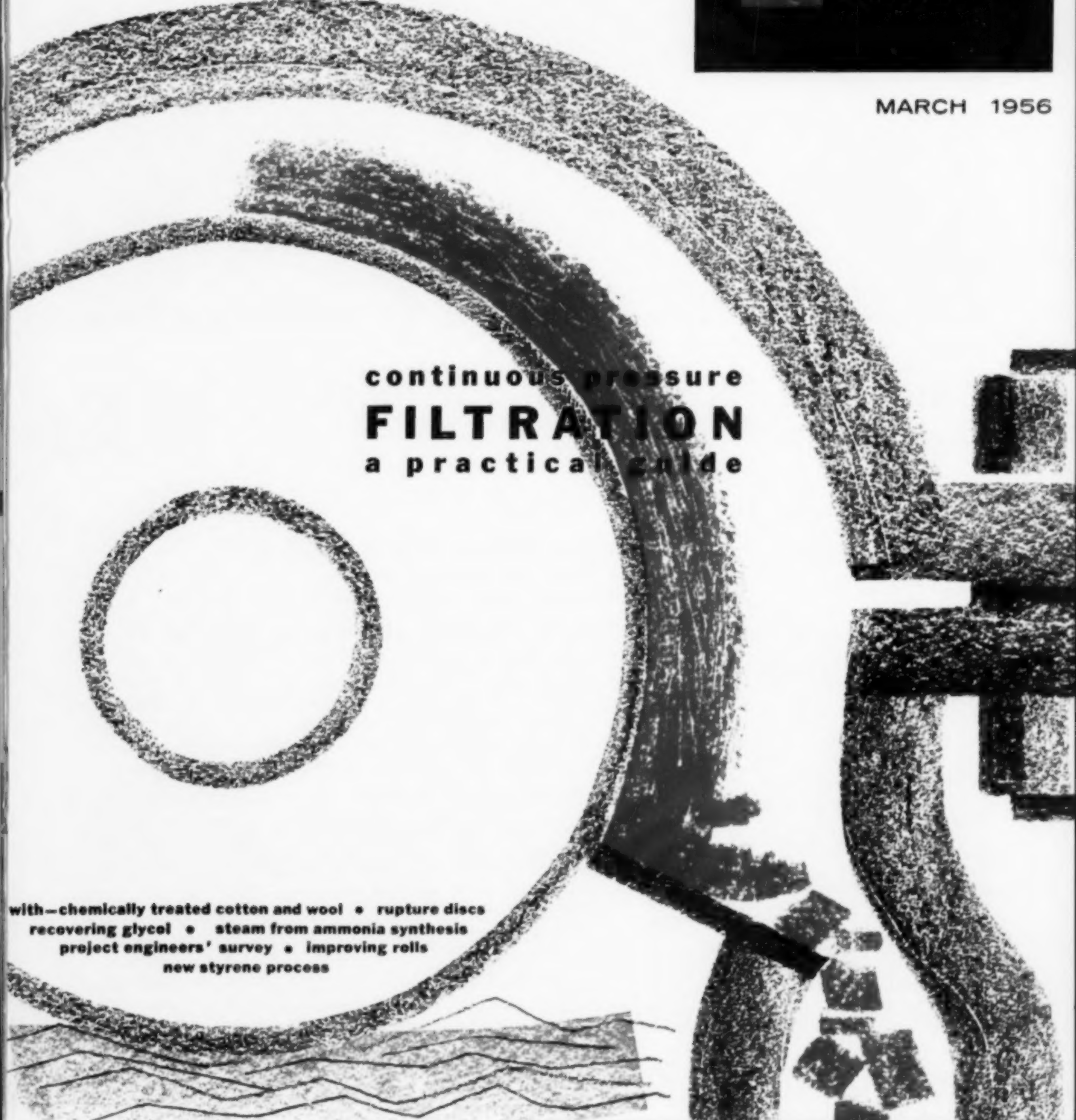
Chemical Engineering Progress

your
NEW ORLEANS
program

two new methods of
HEATER DESIGN
on basis of:
- HEAT TRANSFER
- CRACKING

MARCH 1956



continuous pressure
FILTRATION
a practical guide

with—chemically treated cotton and wool • rupture discs
recovering glycol • steam from ammonia synthesis
project engineers' survey • improving rolls
new styrene process

Chemical Engineering Progress

what's in this issue

March, 1956 • Volume 52, No. 3

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departmental features

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Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester, N.Y.

New trailer-tank saves time and money with liquid transfer

Liquid shipment eliminates drying and packaging, saves the cost and trouble of returning your product to a liquid state upon arrival.

You can now ship, in liquid form, solutions of all acids except hydrofluoric, and all alkalies up to pH 12, to 212° F.

The new Pfaudler glassed steel trailer-tank is delivered complete with signals, reflectors, and hydraulically operated stand wheels to support it independently.

The tank itself is tough Pfaudler glassed steel. This material, besides being especially economical and corrosion resistant, proves ideal for a mobile tank of this type because of its physical strength. In actual demonstrations, a 36" strip of glassed steel can be flexed 6" in either direction without damaging the glass. This is plenty of "give" to absorb the bumps of the road.

The Pfaudler trailer-tank is equipped with sliding hood to protect the vent, manhole and dip pipe at the top. Dip pipe for filling or emptying, glassed both sides and tantalum tipped, reaches down into sump at bottom of tank to assure complete emptying. Tank also has convenient bottom outlet for washout.

For additional details, call your Pfaudler representative or send for Data Sheet 29.

Glassed steel trailer-tank is corrosion resistant, permits low-cost shipment of materials in liquid state.

"Performance" takes driver's seat as basis for selecting equipment

Why Pfaudler created new engineering group

John W. Cosier

To *simplify* selection of equipment that will *perform* as required to obtain desired yields, Pfaudler has established an Applications Engineering Group.

This section, working with design, development, research and production groups, studies each customer's exact production needs, and selects or designs the proper equipment to match these requirements.

Thus, you have even greater freedom from mechanical restrictions than ever before, since each unit of equipment is carefully chosen to provide the yield you want.

This new group of selected engineers—with extensive backgrounds in chemical production problems—is headed by John W. Cosier.

Pfaudler's Applications Engineering Group has four fields of information at its fingertips:

1. Specialized knowledge of all types of glassed steel, stainless and alloy vessels.

2. Pfaudler's 72 years of experience in corrosion-resistant equipment.

3. Experimental, test and user data, compiled in Pfaudler's corrosioneering library.

4. Personal experience of each member of the group.

Pfaudler has already had much experience supplying equipment on a performance basis for: absorption, centrifugation, crystallization, distillation, drying, evaporation, liquid extraction, filtration, flow of fluids, leaching, materials handling and mixing. May we help you?

Example of a Pfaudler application and project engineering: The 25 glassed reactors in this large PVC plant are specially equipped for high internal pressures.

New reactor manhole is bigger, handier

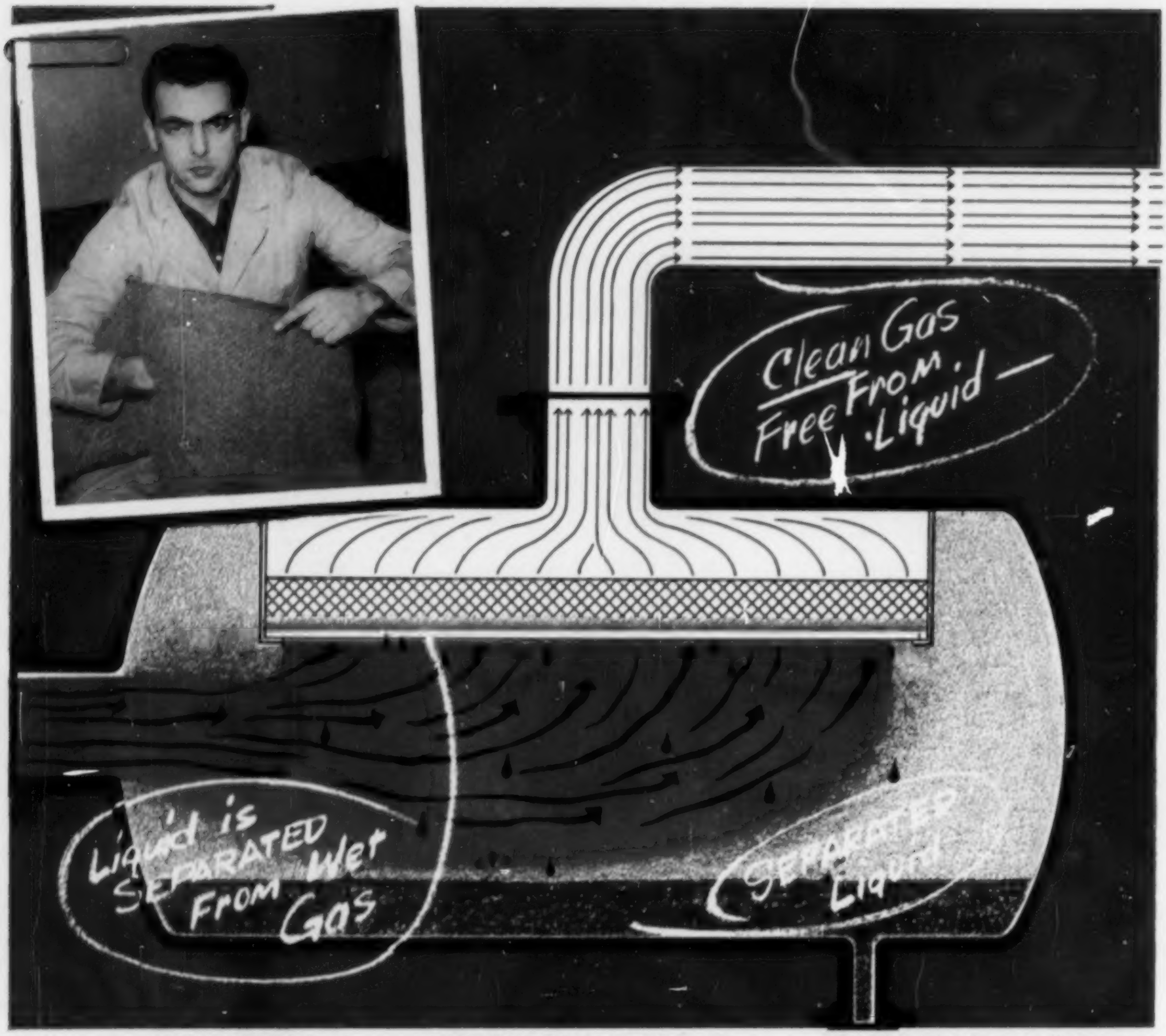
Reaction kettles by Pfaudler in larger sizes are now equipped with an 18" diameter round manhole, compared to the old elliptical 12" x 16" opening.

Also, the manhole has been moved nearer the side of the reactor.

This new manhole not only offers a portly portal for hefty chemical workers (up to size 56!) but also provides easier visual inspection and cleaning, and a safer angle for positioning ladders.

For details of this and other design improvements in the new Pfaudler reactors, call your Pfaudler representative or write for Bulletin 926.

PLASTICS: Corrosion resistance and non-adherence of Pfaudler glassed steel reactors are ideal for polymerization. If your product is sticky, corrosive or sensitive to contamination write or wire us for further details on Pfaudler equipment.


Clean Gas
Free From
Liquid
Liquid is
SEPARATED
From Wet
Gas
SEPARATED
Liquid

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Published monthly by American Institute of Chemical Engineers at 15 North Seventh Street, Philadelphia 6, Pennsylvania. Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only). Canada, $6.50; Pan American Union, $7.50; Other Foreign, $8.00. Single copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

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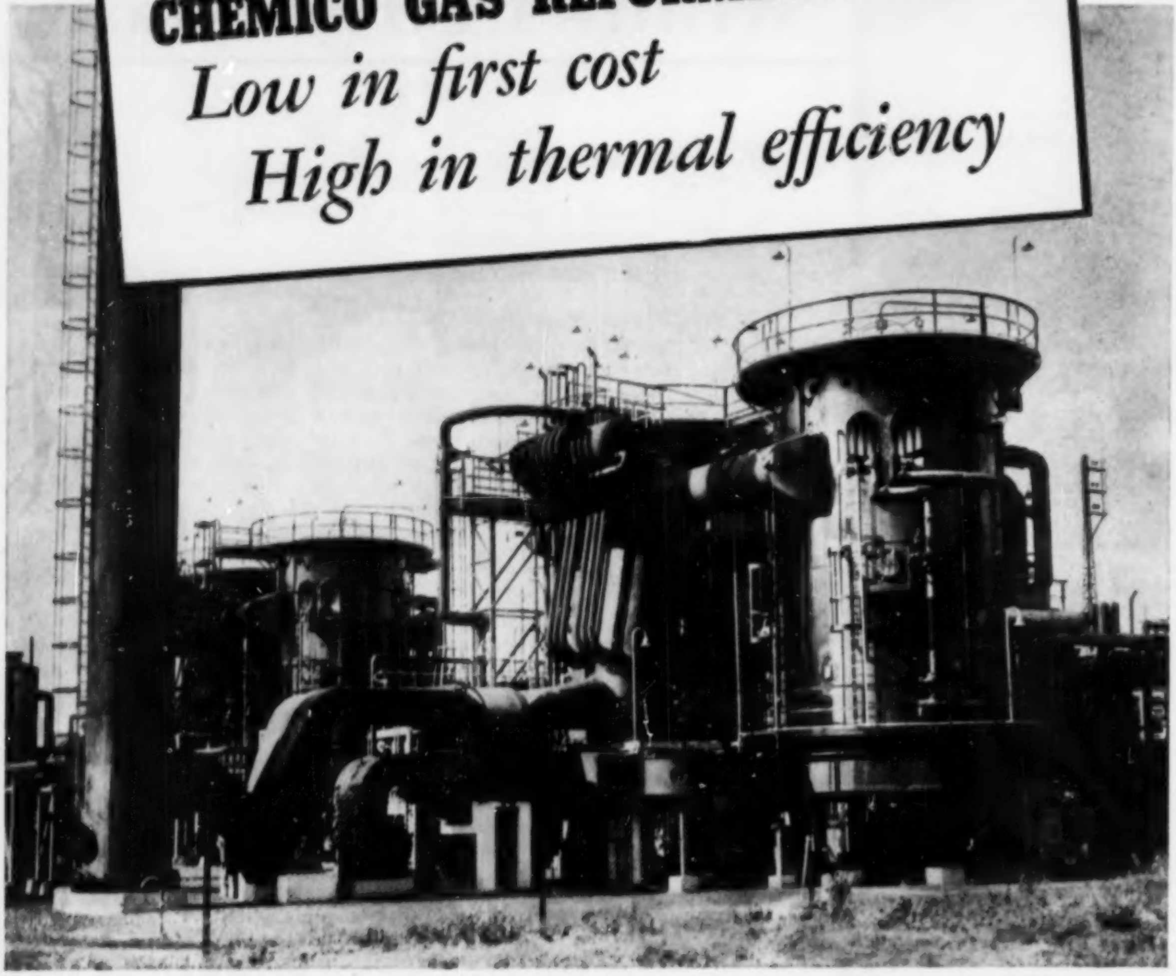
Cover design by Milton Wynne Associates

what's in this issue

(Continued from page 3)

CHEMICO GAS REFORMING PLANT

Low in first cost
High in thermal efficiency



Among the many types of heavy chemical plants Chemico designs and constructs are those for the production of synthesis gas, principally hydrogen.

The gas reforming plant, shown above, is located in the synthetic ammonia works of the Office National Industriel de l'Azote at Toulouse, France. This plant has been operating successfully since 1949 and is now being expanded to double capacity.

Plants of the same type have been designed and put into operation at numerous locations in the United States, and in Canada, Mexico, Italy, Israel and Egypt.

Chemico Gas Reforming Plants are designed to operate at pressures up to approximately 100 psig. The Chemico design provides important advantages . . . low first cost, high thermal efficiency. Construction is simple. The plant is fool-proof . . . requires a minimum of operating and maintenance attention.

CHEMICO
GAS REFORMING PLANTS
are used for making:

- **Hydrogen-nitrogen mixtures for ammonia synthesis.**
- **Hydrogen and carbon monoxide mixtures for methanol synthesis.**
- **Carrier gas for blending with natural gas for distribution by Public Utilities.**
- **Hydrogen for industrial uses.**

CHEMICAL CONSTRUCTION CORPORATION

A UNIT OF AMERICAN CYANAMID COMPANY

Designers and constructors of complete plants and facilities for the chemical and petrochemical processing industries for over 40 years

525 WEST 43RD STREET, NEW YORK 36, NEW YORK

Cable Address: Chemiconst, New York • Technical Representatives: Cyanamid Products Ltd., London South African Cyanamid (Pty) Ltd., Johannesburg

Congratulations Dad. . . it's a valve!

Maybe this is not the way to say it, but we know that every time a new design feature is created to solve a field service problem, hundreds of plant engineers, chemical engineers, maintenance men and purchasing agents look on with the pride of a new father. Our engineering department is the first to admit that the major part of new stainless steel valve design comes from the interchange of problems and experience at our various valve clinics.

Cooper Alloy Area Valve Clinics have been held in most major industrial centers, and our in-plant clinics have been held on the spot in dozens of leading plants, including Dow, DuPont, Mathieson, Celanese, Pfizer and many others. At these meetings our staff presents its findings, listens to the findings of users, specifiers and buyers, and attempts to work out specific problems.

Arrangements for such a clinic in your own plant may be made through our Public Relations Division.

"75 Questions" . . . a selection of those questions asked most often at our clinics, is available on request.

Valve & Fitting Division

COOPER ALLOY
CORPORATION · HILLSIDE, N. J

LETTERS TO THE EDITOR

Money for Movies?

A matter has recently come to my attention which should be immediately rectified by the chemical industry of this country. One hears of the dire shortage of chemical engineers and sees the evidence of many thousands of dollars being spent by chemical companies to interest the graduating seniors in working for them. This is an example of 20-20 hindsight, for there is not one movie or film strip available which is produced solely for the purpose of "selling" the high school senior or college freshman on a career in chemical engineering.

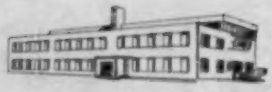
This statement is backed up by evidence in the listing of chemical education films prepared by the Chemical Engineering Education Projects Committee of the A.I.Ch.E. On page 28, section M8 of this listing is the following sad commentary: "M. Research and Careers, miscellaneous Industries. 8. Engineering—work done in certain engineering fields; does not include chemical." This is dated 1942. A recent letter received from F. J. Van Antwerpen, Secretary of the A.I.Ch.E., says this: "Unfortunately the A.I.Ch.E. does not have available a film describing the various phases of work in which chemical engineers are involved, for loan or purchase. We have considered preparing such a film but, at least for the present, the cost is prohibitive."

Here at Ohio State University, for example, we conduct orientation sessions for the freshmen engineering class in which faculty members give the students a preview of a possible career in their particular branch of engineering. Other branches of engineering offer career movies and film strips, which if done properly, serve as a valuable asset to any speaker.

Let's hope that those who read this article will call it to the attention of

(*Continued on page* 14)

SPECIFY EIMCO FILTERS FOR MAXIMUM PERFORMANCE & PROFIT



Research and Development Center — a fully equipped pilot plant for research on solids-liquid separation through filtration.

Engineering — Designed with individual attention towards customer's requirements.

Facilities — includes foundries, fabrication and machine shops covering 26 acres.

Service — for the life of the machine, includes calls by trained personnel. Operational tips and consultation are part of the purchase price.

Eimco Vacuum and Pressure Filters are working in many industries increasing production at lower cost. These industries include: Metallurgical and Chemical Plants; Paint, Varnish and Pigment Plants; Sewage and Industrial Wastes; Pharmaceutical Laboratories; Foods; Coal; Petroleum; Tanneries; Pickle Liquors and Other Wastes; Beet and Cane Sugar; Paper; Steel Mills; Starch, Corn and Potato; Salts and Sand; Water Treatment and many others.

Selecting the unit for the solid-liquids separation problem in your plant is one of your most difficult decisions.

Testing samples under your own conditions, with the numerous variables of materials and equipment available today can be an endless research job.

Eimco's suggestion to companies with problems on solids-liquids separation is that they avail themselves of the data already gathered at Eimco's own Research and Development Center devoted to problems of this type.

Filters of all types are manufactured by Eimco and data on filterability of a product is available on each type of filter to which it is applicable.

Eimco engineers have this exclusive reservoir of experience, gained through more than half a century of service to the processing industries, and the facilities of Eimco's vast manufacturing plants where filters of standard or specialized design are built for each customer's requirements.

Eimco has gained the confidence of many of the world's top processing organizations through suggestions made to simplify flow sheet layouts, plant design or to cut operating costs. These contributions to the processing industry are made possible by new developments in filtration.

Eimco's engineers will be happy to consult with you regarding filtration problems. If further research or test work would seem to be indicated, Eimco equipment is available for test purposes in the customer's plant, on a rental or lease basis with funds thus expended applicable on production size equipment.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Pasadena, Calif. Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

B-179

The separating force produced by this Merco centrifuge is made practical by the strength of its high speed rotor bowl, machined from cast stainless steel with a high nickel content, produced by Electric Steel Foundry Company, Portland, Oregon. Weight of the all-stainless steel rotor assembly on the unit shown above totals 1600 lbs. This centrifuge has a large continuous through-put capacity. In many plants, Merco units run continuously for 24 hours, virtually unattended. Manufactured by Merco Centrifugal Company, San Francisco, California.

Up to 9000G's developed...

thanks to strength of rotor cast in stainless ... that licks corrosion and erosion

Merco Centrifugal Co. tested scores of materials for their centrifuge rotors. And found what they needed in cast chromium-nickel molybdenum stainless steel (ACI Type CF-8M.) These castings safely answer the high strength demands, and in addition, provide resistance to both corrosion and erosion.

Read what a typical customer reported about the performance of a Merco rotor machined from this cast stainless steel containing 10 to 12% nickel:

> "... shows no signs of corrosion after 12 years' service in slurries of warm weak sulfurous and lactic acids, SO_2 vapors, alternate wetting and drying, with liquid and solids passing over the metal surfaces at very high speeds."

Despite corrosives and suspended solids, this rotor has operated for more than a decade with no apparent damage from erosive action. Many similar records confirm that Merco engineers made a wise choice, years ago, when they selected Type CF-8M stainless castings for rotors.

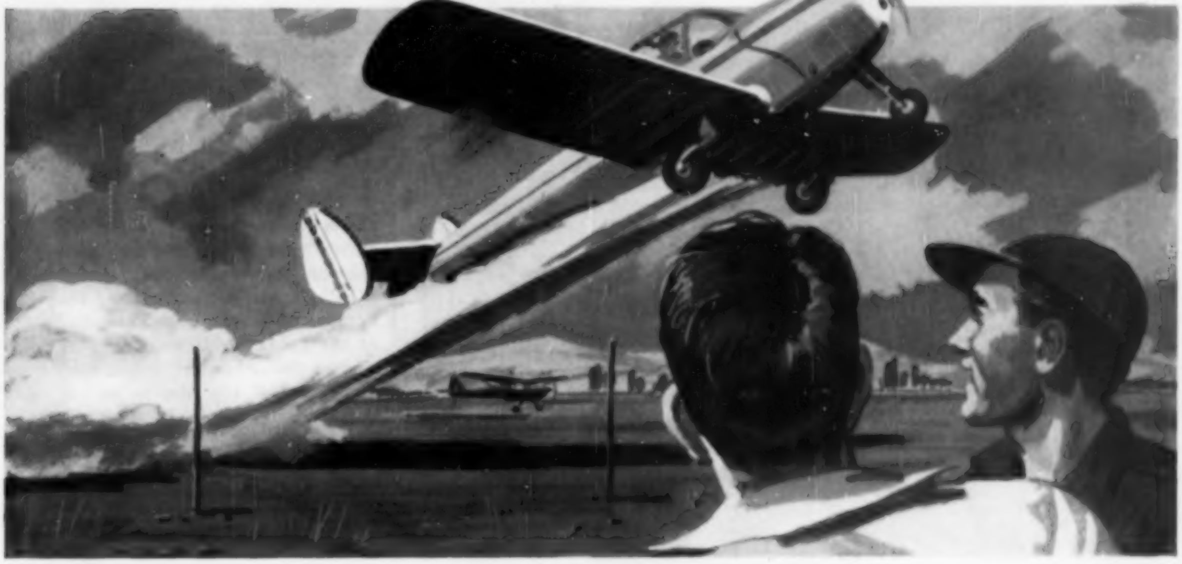
Alloys containing nickel may help *you* strengthen equipment, combat corrosion and erosion, or meet other specific needs. When you face a metal difficulty, send us details. We'll submit suggestions based on wide practical experience. Write for List A of available publications. It includes a simple form that makes it easy for you to outline your problem.

INCO THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N. Y.

Notable Achievements at JPL

***THE FIRST JET-ASSISTED TAKE-OFF** in the United States was made in an Ercoupe monoplane supplied to JPL by the Air Materiel Command and flown by Capt. H. A. Boushey, Jr. at March Field, California in August 1941.*

This was made possible by fitting to the wings six rocket units using the successful rocket propellant GALCIT 27 developed at the Laboratory after two years of research and development.



Continued Leadership in Research

JPL JOB OPPORTUNITIES ARE WAITING FOR YOU TODAY!
In these fields

- CHEMISTRY
- NUCLEAR PHYSICS
- METALLURGY
- SOLID STATE PHYSICS
- CHEMICAL ENGINEERING
- HEAT TRANSFER
- COMBUSTION
- MECHANICAL ENGINEERING

This early success established the special merit of a new type of solid propellant developed at JPL, consisting of an inorganic oxidizer dispersed in a plastic fuel matrix. Propellants of this kind, now manufactured by most rocket establishments, find applications both in modern JATO units and in many current missile designs for the armed services.

In order to maintain this spirit and position of leadership, the laboratory is engaged in research on new types of polymers and in the development of new kinds of propellants. Research that can be mentioned includes organic chemical synthesis, physical chemistry of polymers, mechanical behavior of polymers, formulation of experimental propellants, and combustion research. This work leads to fully-developed propellants, tested in prototype rockets, and ready for manufacture elsewhere.

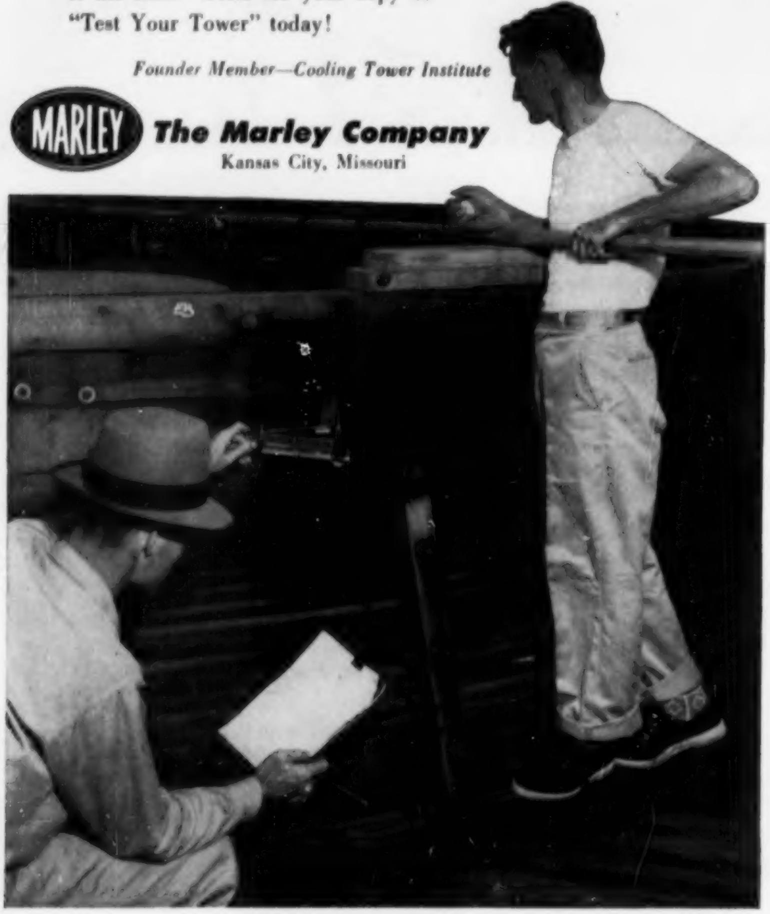
The work in solid propellants has companion efforts, comparable in scope, related to liquid propellants, to materials and metallurgy, and to nuclear propulsion.

Expanding programs are rapidly providing new openings for qualified people. If you would enjoy the challenge of new problems in research, write us today outlining your interests, experience and qualifications.

CALTECH jpl **JET PROPULSION LABORATORY**

A DIVISION OF CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA



Letters to the Editor

(*Continued from page* 10)

management so that they, seeing the problem that exists, will pick up the phone or write to F. J. Van Antwerpen, Secretary, A.I.Ch.E., 25 West 45 Street, New York, New York, and say "We're willing to contribute \$..... to aid in the preparation of a good nonadvertising-type career movie of the chemical engineering profession." There is no cheaper way of providing good chemical engineering recruiting material in the years to come.

Charles E. Dryden
Columbus, Ohio

∫ The Public Relations Committee has for a number of years had a subcommittee investigating the possibility of a film on chemical engineering. So far A.I.Ch.E. has not moved into this area because of costs. Bob York, chairman of the Public Relations Committee, has this on the active list, and it seems obvious that if the film is to be made underwriting will be necessary.

F.J.V.A.

Good Fellow

A remark on my paper "Statistical Methods for Evaluation, etc." in *Chem. Eng. Progr.*, 50, page 200-205 (1954):

M. B. Wilk and O. Kempthorne have formulated a more realistic model for the situation analyzed in my paper. The resulting "expected mean squares" do not agree with those which are correct under the model I used. I recommend the solution contained in their paper published recently in the *Jr. Am. Statisical Assoc.*, 50, pages 1144-1167 (1955).

Henry Scheffé
Berkeley, California

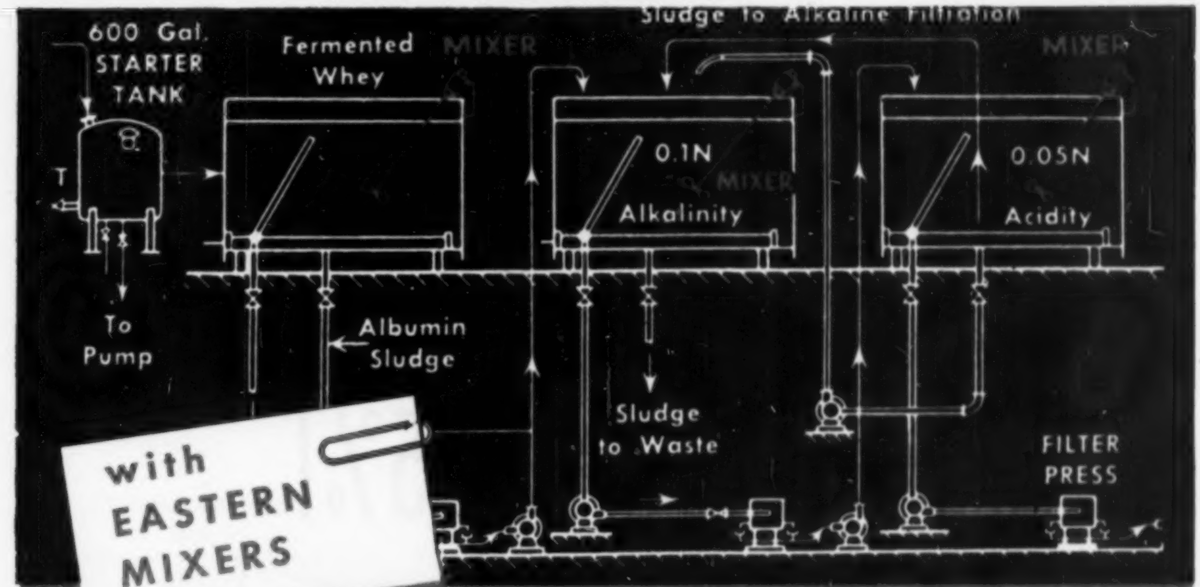
Exception to Salary Comparison

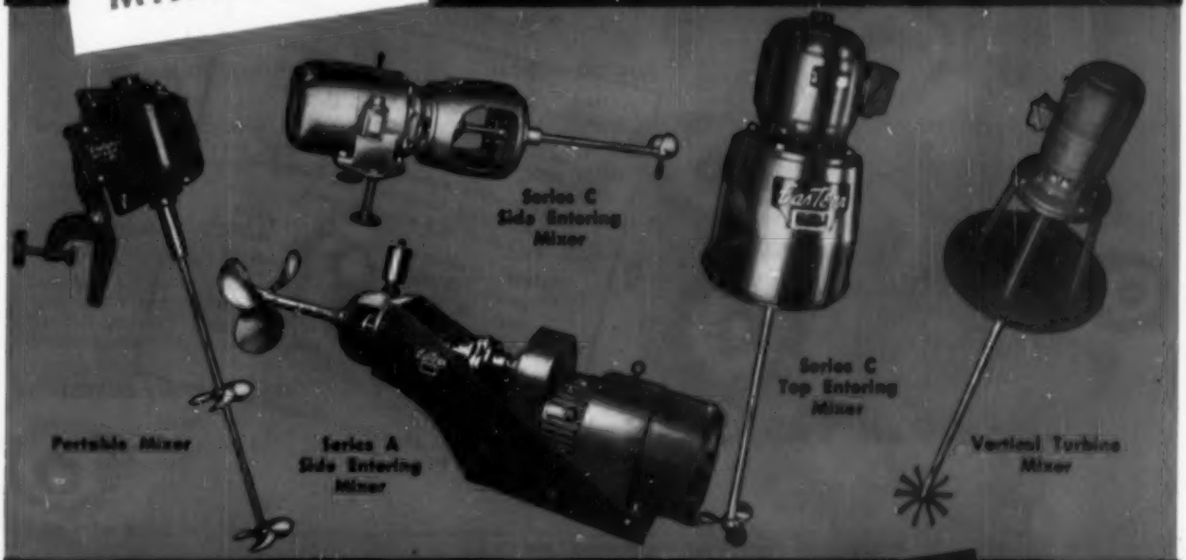
I noted on page 76 of Chemical Engineering Progress for January 1956, a part of a column on engineers and high school teaching. As you will recall, the article gives the salary for a teacher of five years' experience. The article then states ". . . and in all, New York teachers do not fare badly."

I would guess that the salaries shown for the New York City teachers do not compare very favorably with the median salaries to be found in industry. Actually, I would hope that our high school teachers would be the type of people who would command salaries well above the median figures for industry. Even at the salary rate mentioned in the ar-

(*Continued on page* 18)

RELIABLE FLUID MIXING in PROCESSING





Eastern's Mixers are designed to meet the needs of today's chemical and industrial processes. Many types are available to satisfy all conditions of fluid consistencies and tank sizes. Selection may be made from a wide range of horsepower, speed, and construction materials. Motors with various voltage ratings and enclosures are also furnished.

PORTABLE MIXERS

Series H at 1725 R.P.M., Series S at 1125 R.P.M., and Series G at 420 R.P.M. are available in motor ratings from 1/20 to 5 H.P. Also available are special speeds, variable speeds, as well as air driven models.

TOP AND SIDE ENTERING

Series A, extra heavy duty for large tanks, are available in side entering units only within a range of 5-30 H.P. with standard speeds of 280, 420, and 1150 R.P.M.

Series C, for average tank capacities, are available in sizes of ¼ to 10 H.P. at these standard speeds: 1725 R.P.M. (up to 5 H.P.); 1140 R.P.M. (up to 10 H.P.); 420 R.P.M. (up to 7½ H.P.); 280 R.P.M. (up to 5 H.P.). Available in both horizontal and vertical models.

TURBINE MIXERS

Eastern's Top and Bottom Entering Turbine Mixers find particular application where liquid blending requires gentle, yet thorough agitation.

Models are available in sizes from ¼ to 40 H.P. Standard speeds are 56, 68, 84, 100, 125, 155 R.P.M.

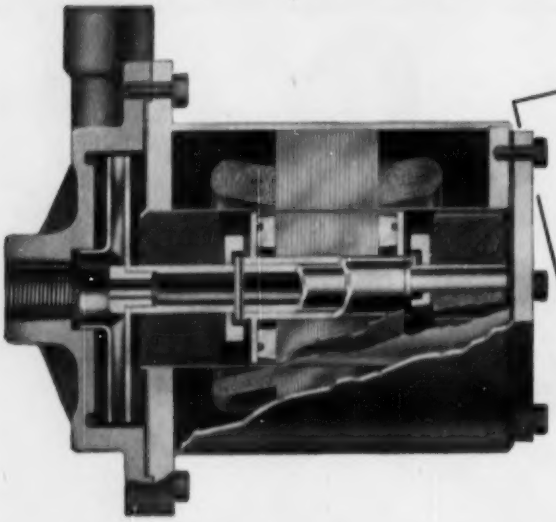
For 3 bulletins covering Eastern Mixers, request Catalog Series 35.

Eastern INDUSTRIES, INC.
Mixer Division
Regent St.,
Norwalk, Conn.

NEW DESIGN FEATURES OF LEAKPROOF "CANNED" PUMP

extend applications . . .

SLASH PRICE 20-25%!



- **New fabricated construction** is simpler . . . permits mass production techniques. You benefit through lower cost.
- **Construction materials** include titanium, Monel, Carpenter 20, Hastelloy B, Teflon and stainless steels.
- **400% greater bearing area** provides greatly extended service life. Bearings are semi-floating . . . easy to inspect or replace.
- **Series S Chempumps** give leak-proof service at heads to 94 feet, capacities to 50 gpm.

Fifteen years of design and operating experience are built into this new *low-cost* sealless Chempump.

You will benefit directly. You get the cost-saving advantages of mass production techniques. You get a choice of materials of construction that can handle practically any known corrosive. You get a "canned" pump that can't possibly leak, that requires no lubrication, that virtually eliminates maintenance. Oversized, semi-floating bearings give thousands of hours of service under difficult conditions . . . cut-outs provide fool-proof motor winding protection for both overcurrent and excessive heat.

The new Series S Chempumps will be available shortly in 1/3 and 3/4 horsepower sizes, with larger units coming. The price is competitive with a quality centrifugal equipped with a mechanical seal. Talk with the Chempump engineering representative in your area about saving through quantity purchases.

- *For complete details, write for Bulletin 1030*
CHEMPUMP CORPORATION
1300 E. Mermaid Lane, Philadelphia 18, Pa.

Chempump

First in the field . . . process proved

Letters to the Editor

(*Continued from page* 14)

ticle, the engineers do not seem to be flocking into the New York public schools. I note that the New York Board of Education has formed a committee with John Dunning as Chairman which will try to get enough science teachers, in particular, to satisfy the City's needs.

C. L. Brown
Linden, New Jersey

It's Only Fair to Say So!

People are always quick to say what is wrong with everything but we seldom hear what is right. The pictures of the officers of the American Institute of Chemical Engineers in the December issue struck me as being so "right" that I want to tell you how much I like them. In fact, I think the whole issue is the best of a year of good issues.

Odon S. Knight
New York, New York

Complainant Decidedly Right!

I wish to register a complaint similar to that I voiced concerning the last Annual Report of the Research Committee. I protest vigorously about the small scale of the graphs which you are now printing in some articles. Specifically, I refer to those on page 561 of the December issue. Try as I will, without a magnifying glass I cannot see whether the ordinates on the left hand chart are cu.in. $\times 10^3$ or 10^2 or what? On Figure 13, I honestly cannot make out the subscript of v in the denominator. And what is the power of N_a in Figure 14?

Not only is the printing on the curves too small, but also the subscripts in the Notation on page 563. Must we go this far? . . .

Walter E. Lobo
Jersey City, New Jersey

∫ Your criticism of the illustrations on page 561 of the December issue of Chemical Engineering Progress is justifiable. We are making valiant efforts to make the graphs accompanying articles readable, for it is of course admissible that no type should be so small that a reader suffers eyestrain.

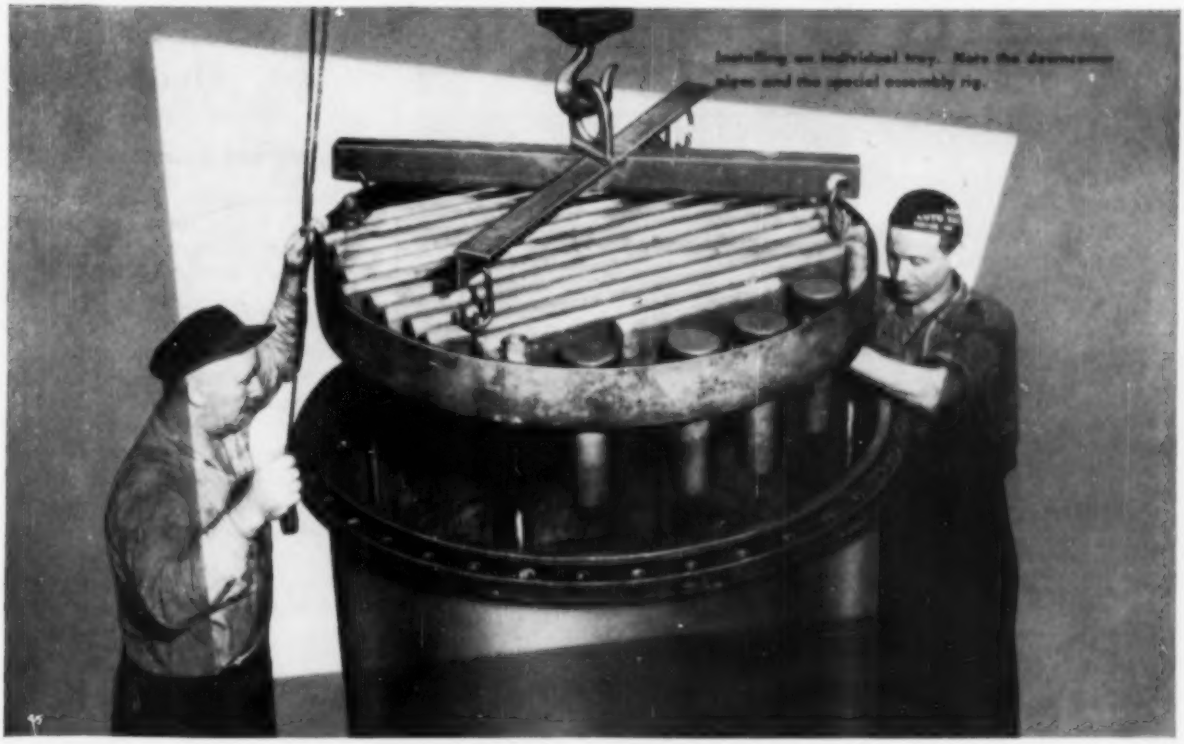
Editor

Articles Appeal

I have read with considerable interest the articles by J. C. Elgin and H. F. Smiddy in the January issue of Chemical Engineering Progress. Both of these articles, in my opinion, are of very high caliber and it is a real delight to see them in C.E.P.

A Wilmington Critic

(*Noted and Quoted on page* 22)



Installing an individual tray. Note the downcomer pipes and the special assembly rig.

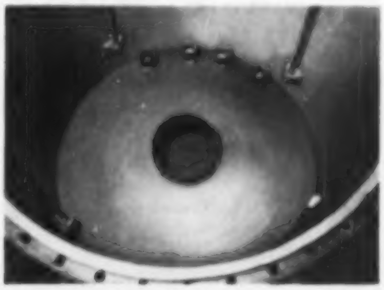
Whitlock Precise Construction Conforms Exactly to your Need . . .

We are particularly proud of two multi-section copper distillation columns we made to close tolerance for a manufacturer of fine chemicals and pharmaceuticals. One of these columns has three and the other seven flanged and bolted sections. The construction is unusual since the entire unit is of copper except for the steel backing flanges, and the tolerance is extremely close with the large 49¼" inside diameter. To assure minimum vapor short circuiting, a snap-type seal ring construction at the individual trays is included. However, the fabrication is so precise that a nearly perfect metal-to-metal contact between shell and tray is obtained without this extra precaution.

In strict accordance with Whitlock Manufacturing Standards, all welding operations on the copper employ the inert gas-shielded arc technique. These columns are an excellent example of the Whitlock Precise Construction available to our customers.

If your problem is a knotty one involving precise construction, unusual materials, or special design, you will find our experience and facilities very helpful. Whatever your heat exchanger problem . . complex or simple . . . ask us for recommendations. Our engineering, designing, manufacturing, and testing facilities are at your disposal.

One of the individual copper sections, showing the steel backing flanges and the perforated bubble caps and downcomers arranged about the tray. Each section contains five trays.



This special intermediate column section, before the installation of trays, shows the flanged, convex copper head with a vapor opening and a part of the downcomer assembly.

Whitlock

THE WHITLOCK MANUFACTURING COMPANY
97 South Street
West Hartford 10, Conn.
In Canada:
Darling Brothers, Ltd., Montreal

Designers and builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.

Noted and Quoted

Education and Research

What is research? There are many millions of dollars spent each year on work that is classified by some as industrial research, but I would not so classify it. . . .

A proper objective of education is first to develop well balanced men and women who not only are able to fit into society but also who have the ability to lead society. This objective is just as much a responsibility of engineering education as it is of other branches of education such as law, literature, theology and journalism.

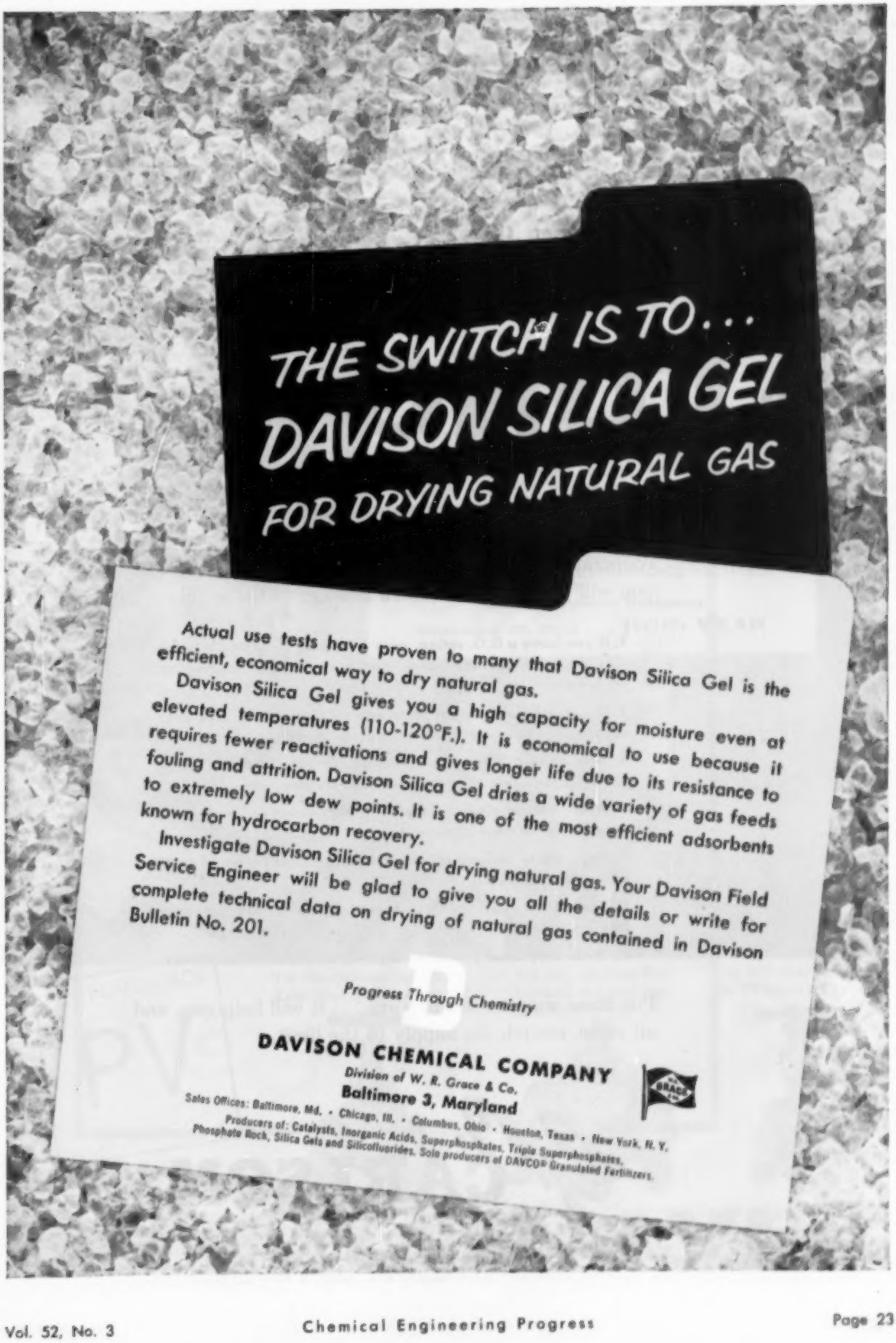
The engineer should not be trained specifically for industrial research. His education should not be given undue emphasis even though his immediate interests may lie in that direction. . . .

The engineer should be given broad fundamental training which is applicable to all fields of engineering practice. The engineer of tomorrow must grapple with problems that the engineer of today has been unwilling if not unable to face. The engineer, together with his scientist counterpart, is primarily responsible for the creation of the American economy. Nevertheless, the modern engineer has devoted no significant effort toward directing this economy. . . .

Certainly the engineer entering industrial research should be well trained in inductive as well as deductive reasoning. However, the way our present day engineering curricula are presented, insufficient attention is devoted to the development of the student's ability to think inductively. On the other hand, excellent intensive training is given the student in deductive reasoning. One of the reasons for this may be that it is far easier to present a subject to students by deductive methods rather than by inductive processes. . . .

People who have the responsibility for selecting engineers for high positions are afraid of the poorly balanced, narrowly trained men. A man may be smart, sharp, shrewd, clever, a good scholar—even brilliant—but is he sound? Many over-estimate the value of education and brilliance. These are certainly no substitutes for sound judgment—no more so than is knowledge a substitute for wisdom. There is no substitute for soundness of judgment.

(*Continued on page 26*)


THE SWITCH IS TO...
DAVISON SILICA GEL
FOR DRYING NATURAL GAS
Actual use tests have proven to many that Davison Silica Gel is the efficient, economical way to dry natural gas.
Davison Silica Gel gives you a high capacity for moisture even at elevated temperatures (110-120°F.). It is economical to use because it requires fewer reactivations and gives longer life due to its resistance to fouling and attrition. Davison Silica Gel dries a wide variety of gas feeds to extremely low dew points. It is one of the most efficient adsorbents known for hydrocarbon recovery.
Investigate Davison Silica Gel for drying natural gas. Your Davison Field Service Engineer will be glad to give you all the details or write for complete technical data on drying of natural gas contained in Davison Bulletin No. 201.
Progress Through Chemistry
DAVISON CHEMICAL COMPANY
Division of W. R. Grace & Co.
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Sales Offices: Baltimore, Md. • Chicago, Ill. • Columbus, Ohio • Houston, Texas • New York, N. Y.
Producers of: Catalysts, Inorganic Acids, Superphosphates, Triple Superphosphates, Phosphate Rock, Silica Gels and Silicofluorides. Sole producers of DAVCO® Granulated Fertilizers.

How we S-T-R-E-T-C-H valve life

Every Powell Valve comes with a long, dependable life built-in. We make certain that every Powell Valve will give long, trouble-free service through careful quality control of every step of manufacture.

Quality control begins with the very materials and metals of which Powell Valves are made. For instance, the tensile strength test—stretching metal to the breaking point—is one of the numerous ways that *Powell Valves have Performance Verified.*

As a final step in manufacture, every Powell Valve is subjected to *an actual line test.* Because of Powell's painstaking quality control, plant shutdown through valve failure is greatly reduced. Records from refineries, power and industrial plants the world over prove it.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our COMPLETE *quality line* which has PERFORMANCE VERIFIED.

The Wm. Powell Company

Cincinnati 22, Ohio . . . 110th YEAR

PERFORMANCE PV VERIFIED

FIG. 2475—Stainless Steel O.S.&Y. Globe Valve For 150 Pounds W.P.

FIG. 1559—150-Pound Steel Lubricated Plug Valve. Sizes 1" to 4".

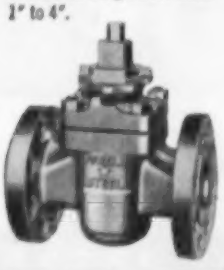


FIG. 3003—Steel Gate Valve For 300 Pounds W.S.P.

POWELL VALVES

BRONZE, IRON, STEEL AND CORROSION RESISTANT VALVES.

Noted and Quoted

(*Continued from page 22*)

Therefore, it is urged that the engineering student not be trained specifically for research. Give him broad intensive training. Develop his sense of proportion. Teach him to think inductively as well as deductively. Give him training in the application and development of his imagination. Allow him the opportunity to develop his ingenuity.

In essence, I hope the engineering schools will turn out well balanced engineers who can practice successfully in any field if their aptitudes are compatible.

Chalmer G. Kirkbride
"Education for Research in Industry"
Journal of Engineering Education

The Engineer's Contribution to Society

The engineer . . . can help lead the way in preparing our nation's defenses, materially and mentally, not only against nuclear attack, but also against toxicological attack if it should ever again become necessary to protect our freedom.

The role of the scientist is to think . . . ; the role of the engineer is to transform those thoughts into the realm of practicability. It is apparent throughout the world that engineers and scientific research men, working side by side, are all important to the structure of today's civilization.

Progress being made today, just as it was a hundred years ago, greatly reflects the engineer's mind. The type of thinking instilled in a man by engineering training and experience is giving us great industrial, educational, administrative, and military leaders. So long as this condition exists, our nation will remain strong and progressive.

Major General William M. Creasy
in speech before A.I.Ch.E.

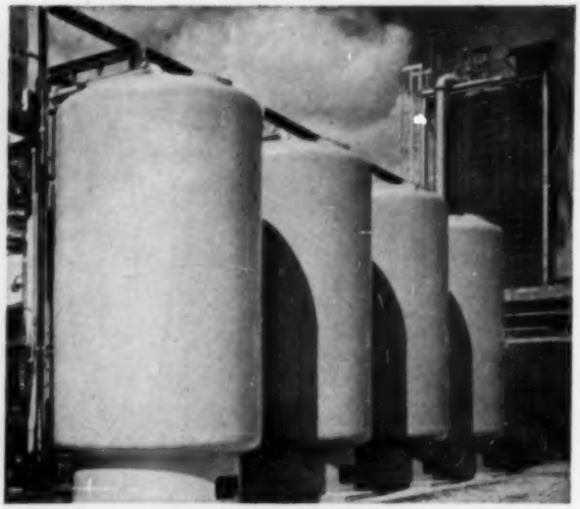
This Wonderful Age!

The great promise for the future is in the technical potentialities of our age. . . . Now science and technology are reaching the stage where new resources can be created where none existed before.

The discovery of nuclear energy symbolizes this radical change in the promise of man's future. Quite aside from the fact that coal and oil were distributed by nature in such a way as to benefit only a few nations, supplies of these fuels were sufficient to power our

(*Continued on page 30*)

ENGINEERING. Permutit engineers work with your staff or your consulting engineers to design all or any part of your water conditioning system.



EQUIPMENT. Permutit supplies complete equipment. Critical parts such as valves, chemical feeders and controls are designed and made by Permutit.

How Permutit® Solves a Water Problem

U. S. industry is faced with using lower grade water. Results: possible boiler scale, turbine deposits, corrosion of pumps and piping . . . also stains, blisters and other problems in plating, rinsing, dyeing and chemical processing.

• **For expert answers,** more and more management men and their consultants are buying the complete service offered by leading water-conditioning firms. Here's how Permutit (rhymes with "compute it"), a pioneer and largest in the field, tackles a water problem:

• **Water analysis,** study of the problem and past experience provide data on possible methods of treatment. The process offering the best balance of initial and operating cost vs desired quality of treated water is selected.

• **Complete proposal** by Permutit engineers covers type, size and capacity of equipment, price, any special engineering services and performance guarantees.

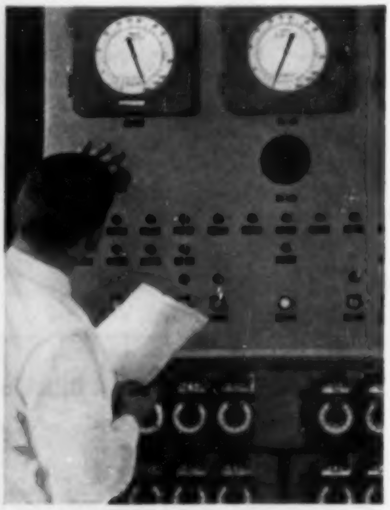
• **Manufacturing** – After the proposal is accepted, Permutit designs the entire project, schedules assembly and shipping. Critical parts, ion exchange resins, control panels are all made in Permutit plants. (No other U. S. firm makes all these components.)

• **Test runs** – Where required, Permutit checks the installation, supervises start-up and initial operation, trains permanent operating personnel.

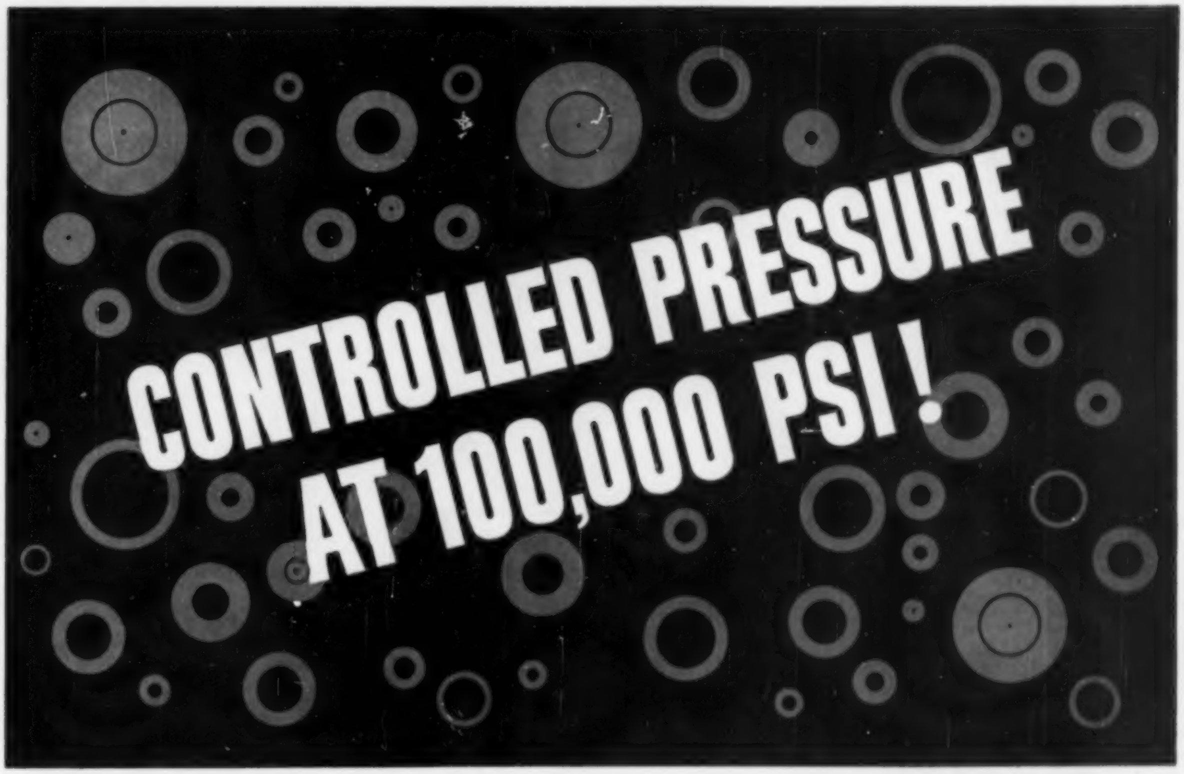
• **For further information** look up the Permutit office in your city or write to The Permutit Company, Dept. CEP-3, 330 West 42nd St., New York 36, N. Y.

WATER ANALYSIS. Permutit's modern water-analysis laboratory tests over 1200 samples a month!

ION EXCHANGE RESINS. Permutit makes its own ion exchange resins, natural and synthetic zeolites.



AUTOMATIC CONTROLS to ensure optimum results are designed, assembled, wired and tested by Permutit.



Superior super pressure quality tubing has been used to handle internal pressures from 15,000 to 100,000 psi—offers high fatigue strength, high chemical resistance, high pressure resistance

Safe and efficient service at extremely high pressures makes Superior super pressure tubing preferred for hydrogenation process equipment, high pressure autoclaves, and pilot plant installations in chemical and oil refining plants.

Superior produces this tubing from specially selected raw materials which have had the inside surfaces conditioned to remove fissures and other defects. In processing, special degreasing operations are performed on the tubing, and the inside diameters are sand blasted to insure a clear, smooth surface.

Two types of Superior super pressure tubing are available: a single wall mechanical tubing and a double wall, or composite unit, made from two thinner tubes.

Super pressure tubing is produced in an annealed condition and in ⅛ hard temper, and to mechanical properties specified by the customer.

This tubing is offered in the austenitic stainless steels, Types 304, 316, 321 and 347, and in AISI 4130 alloy steel. It is produced in sizes ⅛" OD x 1/16" ID up to ¾" OD x 1/16" ID. Minimum order quantity for mill production is 50 ft. per size and analysis.

Superior rigidly inspects all super pressure tubing for defects such as fissures by visual and microscopic inspection methods. Each length is hydrostatically tested to 5000 psi—upon request, up to 60,000 psi.

If you have a tubing problem in high pressure processing—or of any other nature—call on Superior. Write Superior Tube Company, 2011 Germantown Ave., Norristown, Pa., for Data Memorandum 22.

The composite type stainless super pressure tubing offers the advantage of having the inner and outer tubes independently worked to mechanical property requirements and of different alloys being combined for strength and corrosion resistance.

SUPER PRESSURE TUBING MINIMUM BURSTING PRESSURES FOR AUSTENITIC STAINLESS STEELS AND 4130 ALLOY STEEL

	MAXIMUM WALL			
OD	.053	.095	.156	.218
⅛	*97,200 84,400			
¼	*40,200 34,800	82,000 71,000		
½	*17,400 15,000	33,500 29,100	62,500 54,000	
¾	*13,600 11,800	25,000 21,600	47,600 40,300	72,600 63,000

*Top figures all Austenitic Stainless Steels
Bottom figures all 4130 Alloy Steel

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010" to ⅝" OD—certain analyses in light walls up to 2½" OD

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331

Noted and Quoted

(Continued from page 26)

industrial civilization for only some fifteen generations. Of these, seven are already past. Philosophically, one might say that man was given easy access to the fossil fuels to develop his mechanical civilization to the point where he could provide a more sophisticated fuel. This he has done in our generation, for the nuclear fuels can provide us with efficient sources of energy for a thousand generations in the future. But even more important, these nuclear fuels are abundant, cheap, and transportable, and potentially available to people everywhere.

Nuclear energy symbolizes the potentialities of technology and science for the fulfillment of man's material needs.

What are the critical levels of science and technology that must be achieved in underdeveloped areas if a renaissance is to arise? Science and technology are not the only elements that must be stimulated. But they are important ones, for they open new frontiers and new resources that are vital to the optimism that must be generated in economically backward areas. . . .

In the field of science education, we find a dearth of suitable textbooks in all languages, except those of northern Europe. In such an important language as Spanish, textbooks in many disciplines are far out of date. Without adequate texts there is little opportunity for the youth of a country to become inspired by the potentialities of science. Certainly the cost of translation and publication of critical texts on an up-to-date scale is small compared to our total expenditures for aid programs. . . .

In many localities opportunity for scholarly training is small. Recently, one country could not find a single national to represent its interests in utilization of nuclear energy. . . .

Often the science graduate in an underdeveloped area has no opportunity for employment, . . . Here, the international organizations can play a most important role by firing the imaginations of leaders of governments to the opportunities for research and development . . . For substantial indigenous economic growth cannot occur today without a basic minimum of skill in science and technology.

L. V. Berkner
Speech before Fifth National Conference of U. S. National Commission for UNESCO

(More Noted and Quoted on page 36)

Noted and Quoted

(*Continued from page 30*)

Calling Scientific Recruits

The various countries and different industries need, above all, young people who have had a thorough grounding in the methods of science and technology without necessarily possessing, at the conclusion of their studies, the highly specialized knowledge of a subject that they will easily acquire soon afterwards. . . . A student who has thoroughly grasped the meaning of scientific method, and has been able to apply it in several branches of physical science, should be capable, at the end of his university studies properly so called, of becoming very quickly, in a specialized training establishment—or even by practice—a nuclear research scientist or engineer.

As regards atomic energy, it is clear that the general education provided should include certain essential branches of mathematics, physics and chemistry, and it would be dangerous not to add some study of biology. It is only when a very sound basis of this kind has been laid, that the highly specialized fields of knowledge with which the engineer and research scientist must be familiar if he is to succeed, can safely be tackled. . . .

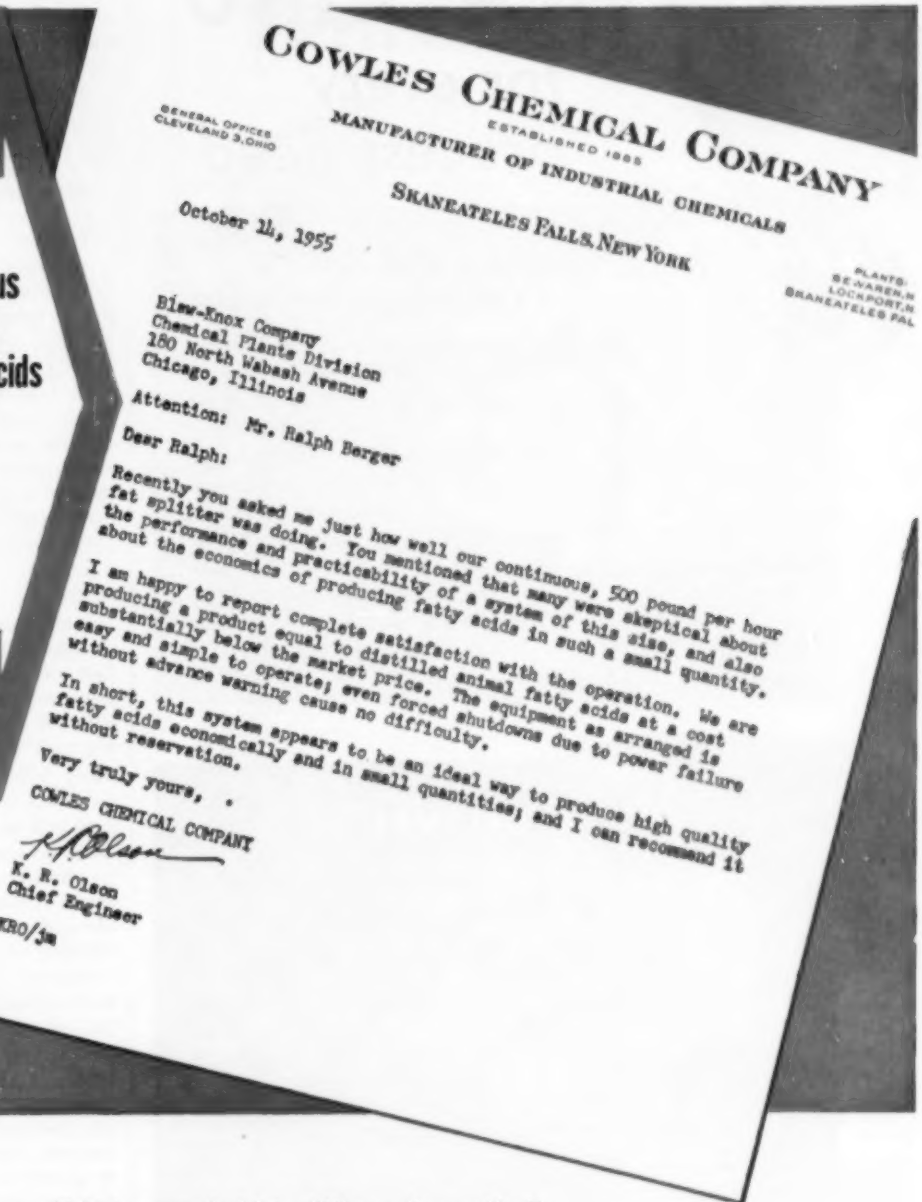
All these considerations focus attention on what is perhaps the most fundamental problem . . . . , namely how to obtain, in the years ahead, the required number of students who have emerged from their university course of study with a sufficiently intimate knowledge of the methods of science and technology to enable them to play an active part in the development of atomic energy, as, for that matter, in that of other new branches of science. It is very disquieting to observe that, far from increasing rapidly, as one might have expected, the number of science students in universities remains stationary and sometimes even shows a tendency to decrease.

In some big countries it is already certain that scientific research and industry are going to be faced with a serious lack of recruits. Public authorities, and public opinion itself, must be awakened to this very grave danger. Directors of educational establishments, teachers in all grades of schools and universities, parents of young people pursuing their studies, must be warned of this threat so as to avert it as far as lies within their powers. . . .

Pierre Auger
"The Training of Research Staff for the Peaceful Uses of Atomic Energy."

(*Marginal Notes on page 42*)

Blaw-Knox small-scale continuous fat splitter produces "high quality fatty acids economically and in small quantities... is easy and simple to operate"



COWLES CHEMICAL COMPANY
ESTABLISHED 1885
MANUFACTURER OF INDUSTRIAL CHEMICALS
SKANEATELES FALLS, NEW YORK

GENERAL OFFICES CLEVELAND 3, OHIO

PLANTS: SEWAREN, N. LOCKPORT, N. SKANEATELES FAL

October 14, 1955

Blaw-Knox Company
Chemical Plants Division
180 North Wabash Avenue
Chicago, Illinois

Attention: Mr. Ralph Berger

Dear Ralph:

Recently you asked me just how well our continuous, 500 pound per hour fat splitter was doing. You mentioned that many were skeptical about the performance and practicability of a system of this size, and also about the economics of producing fatty acids in such a small quantity.

I am happy to report complete satisfaction with the operation. We are producing a product equal to distilled animal fatty acids at a cost substantially below the market price. The equipment as arranged is easy and simple to operate; even forced shutdowns due to power failure without advance warning cause no difficulty.

In short, this system appears to be an ideal way to produce high quality fatty acids economically and in small quantities; and I can recommend it without reservation.

Very truly yours,

COWLES CHEMICAL COMPANY

K. R. Olson
Chief Engineer

KRO/jm

. . . efficient, economical fat splitting units, specifically designed for small scale production, utilizing the basic principles of modern processes, are recommended by Blaw-Knox

1. for supplementing larger units to avoid interruption of processing small lots of different stocks

2. for supplying small local requirements in areas that are remote from large producers.

split it continuously
and you'll split it more profitably . . .
in large or small scale operations

BLAW-KNOX COMPANY *Chemical Plants Division*
Chicago 1, Illinois / Pittsburgh 22, Pennsylvania
Birmingham, New York, Philadelphia, San Francisco, Washington, D.C.

MARGINAL NOTES

Nuclear and Radiochemistry. G. Friedlander and J. W. Kennedy. John Wiley & Sons, Inc., New York (1955), 468 pages, $7.50.

Reviewed by Ernest J. Henley, Assistant Professor, Chemical Engineering, Columbia University, New York.

Having used extensively the first edition of this book, "Introduction to Radiochemistry," both as a textbook and a reference book, I was interested in this new edition. Not only is it welcome for its newness and enlarged print size but also for its expanded stature and context.

In 1949 when the first volume was produced, the term *radiochemistry* was thought to apply to both reactions of nuclei and properties of the resulting species to tracer experiments. Apparently usage of the term today has been restricted to the latter field, hence the significant change in the title of this edition.

Expansion and revision are evident throughout the book. Anyone in the fields of nuclear and hot atom chemistry will find this new edition a most valuable addition to his library. As a textbook it is unsurpassed; however, those who bought the first edition merely to obtain an introduction to the field will be disappointed in this book. Much of the new material consists of treatments of *fringe* topics more fully covered in other books. One may cite the new sections on Nuclear Reactors, Military Applications, and Radiation Chemistry as examples. In all these sections the material is too cursory for the initiated and too advanced for the novice.

"Nuclear and Radiochemistry" is a *must* for anyone working in these specific fields. To get the full import of the author's message, a good background in physical chemistry is requisite and a knowledge of chemical physics is recommended.

Accidental Scientific Discoveries, Compiled and Edited by B. E. Schaar, Schaar and Company, Chicago, Illinois (1956), 64 pages.

Twenty important scientific discoveries are described in a new booklet entitled, "Accidental Scientific Discoveries," now available from Schaar and Company, Chicago.

Compiled and edited by Bernard E. Schaar, recently retired president of the company, each article summarizes the

work of such men as Priestley in the discovery of oxygen, Roentgen with X-rays, and Courtois with iodine. The booklet also includes stories about the discovery of rayon, insulin, petroleum jelly, crystallography, aniline dyes, plastics, and other historic advances in science. Keynoting the entire theme of the series is the preparedness of each scientist in seizing upon chance occurrences to direct his investigation toward a successful goal.

BOOKS RECEIVED

Engineering Drawing and Geometry. Randolph P. Hoelscher and Clifford H. Springer. John Wiley & Sons, Inc., New York (1956) $8.00.

The Systematic Identification of Organic Compounds. A Laboratory Manual. 4 ed. Ralph L. Shriner, Reynold C. Fuson, and David Y. Curtin. John Wiley & Sons, Inc., New York (1956) 426 pages, $6.00.

Revista Interamericana de Bibliografia (Inter-American Review of Bibliography). October-December, 1955, Vol. 5, No. 4, 410 pages. Published four times a year, with a separately issued annual index and table of contents. Subscription rate in the Americas and Spain $3.00 a year; in all other countries $3.50; a single copy is $1.00.

Collected Technical Papers of American Society of Tool Engineers, Detroit, Michigan (1955), 347 pages, $5.00. A leatherette-bound volume of 1955 collected technical papers presents in one volume all the papers and panel discussions presented at the 23rd annual convention of A.S.T.E. in Los Angeles.

Proceedings of the Eighteenth Annual Short Course for Water and Sewerage Plant Superintendents and Operators, March 16-18, 1955. Sponsored by General Extension Division and the College of Engineering of Louisiana State University in cooperation with the Louisiana State Department of Health and the Louisiana Conference on Water Supply and Sewerage. Louisiana State University and Agricultural and Mechanical College, Baton Rouge (1955), 202 pages, $1.50.

Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds. Frederick D. Rossini, Kenneth S. Pitzer, Raymond L. Arnett, Rita M. Braun, and George C. Pimentel. American Petroleum Institute Research (Project 44). Carnegie Press, Pittsburgh, Pa. (1953), 1050 pages, $7.00.

CEP trends / TITANIUM

Titanium, newest and fastest growing of the industrial metals, is finally hitting full stride after a slow start. Demand this year is expected to be about double what it was in 1955, and production is also expected to be nearly doubled, although from present indications there will still be substantial surplus output which will be bought by the government for stock-piling.

Fabricators, however, will be pushed to meet the expected demands, mainly from the Air Force, while industrial uses, especially in the chemical field, are beginning to grow.

Leaders in the industry estimate that output of titanium sponge this year will be about 15,000 tons against about 8,000 tons in 1955, 5,000 in 1954 and only 2,240 in 1953. In the past two years demand was actually only around 30% to 35% of the available supply, which has meant that industry has been chary about entering the field without government contracts to take their output.

Dollar-wise, titanium is already becoming a sizeable business. Sales of fabricated or milled products in 1955 are estimated at $60,000,000 and sales of sponge metal added about $30,000,000 to the total. Fabricated products took about 1,900 tons last year against 1,300 tons in 1954. This year the government is expected to want 4,000 to 4,500 tons of mill products which will have a dollar value of $120,000,000, while sponge sales should be about $40,000,000.

By the end of this year installed and completed plant capacity will be producing at the rate of 22,500 tons of sponge yearly. Of this, 3,600 tons will come from the plant of Titanium Metals Corp. at Henderson, Nev., now running full, 3,600 tons from the Du Pont plant, 6,000 tons from the plant of Cramet, Inc. at Chattanooga, Tenn., and 1,800 tons from the plant of Dow Chemical Co. The new plant of Union Carbide's Electro-Metallurgical division at Ashtabula, O. is in the pilot stage and is expected to be running about the middle of April. It will have 7,500 tons output.

Government Subsidy

The Du Pont Co. was negotiating with the government last year to build a $40,000,000 plant to produce about 8,000 tons yearly. However last September the government suspended its program to encourage private industry to enter the field by advancing funds to build sponge plants and giving contracts. Negotiations with Du Pont were dropped and the firm decided not to go ahead with a sponge plant at this time. It is understood that a titanium oxide plant may be built at the site. Reason for the slowup in the government subsidy program was that contracts now outstanding are more than large enough to supply estimated needs for the next several years. The stock-pile of sponge so far built up will provide supplies for any emergency. Meanwhile, more fabricating capacity would appear to be the next major requirement.

Titanium is especially important to the armed forces because its alloys weigh only about half as much as steel alloys of approximately equal strength. Although titanium does not stand some of the extreme temperatures which original enthusiasts hoped for, it holds up better than stainless steel at temperatures up to 900° F. and for brief periods will stand up to 2,000° heat. Alloys of other light metals are much more vulnerable to heat. Titanium also has outstanding resistance to corrosion by salt water and chemicals.

Production Problems

As with all new metals, titanium development has been retarded to some extent by technical difficulties, especially in fabricating. When at melting temperatures it eagerly combines with almost any other material, so many new techniques had to be developed, including treatment under vacuum. Keeping hydrogen content to a minimum is essential because hydrogen makes the metal brittle. A method for producing the metal on a commercial scale was not developed until 1946 and for a number of years progress was slow. Output as recently as 1950 was only 70 tons of sponge.

Alloys and Products

The titanium industry is now concentrating on quality improvement not only in the sponge metal but in the specifications for sheets and other shapes. A number of excellent alloys have been developed using manganese, aluminum, tin and vanadium, and laboratories are hard at work developing new ones, some of which will come into pilot plant production this year.

To meet the doubled demand for fabricated titanium products this year, the Mallory-Sharon Titanium Corp. of Niles, O. has acquired the Niles rolling mill from Sharon Steel Corp. which will be adapted to titanium handling. The bulk of its output will go to jet airplanes and air frames.

Japan became an important factor in titanium in 1955, exporting the major part of its output to the United States. Japanese supplies came to 500 tons last year against 225 tons in 1954. Late last year the Commodity Credit Corp. arranged to trade farm products for 2,000 tons of Japanese sponge to be delivered over a two year period at a price of $3.50 a pound against the current American price of $3.45 a pound. This is expected to require an expansion of Japanese facilities.

opinion and comment

THE O.R. ATTITUDE

Some time ago there was a man whose unusual inquisitiveness and effort resulted in the development of processes of great importance to the chemical industry.* This man saw with great openness of mind things which his fellows were overlooking in an era when science was either little known or not taken seriously. It made him outstanding.

Today it can be argued that discoveries of importance can hardly be made by the individual unless he is heavily equipped with devices, and even then only with the consultative services of specialists. As a people, we have come to believe that to be important, a discovery has to be large or spectacular, like a cure for polio, or a means for ventilating the Los Angeles basin.

It has become far too easy to relegate the essentially practical discoveries of Acheson's day to a category which we would term unimportant today, simply because the same kind of experiments today would, in the advanced state of our scientific progress, produce only *practical* results, not fundamental, and not, therefore, spectacular.

That this point of view is erroneous is demonstrated by the emergence of Operations Research—a technique which is growing rapidly in stature as both useful *and* practical.

Operations Research, perhaps fortunately, is off to a sizeable start in industry, utilizing large teams of workers who often get their final results from the more spectacular large computers. This has given it the dignity of being *major research*, and often enabled it to accomplish tasks which represent major achievements in magnitude alone.

We have it from good authority, however, that the basic member of an operations research team is a person familiar with the overall processing or other operations under study, one who is unusually inquisitive and imaginative—highly sensitive in other words, to environmental factors which contribute either to good performance or bad performance. According to such a description, it would sound as if the modern day O.R. man needs to possess some of the qualities of an Acheson.

A corollary might very well be that most chemical engineers could benefit from adoption—within the limits of their flexibility—some of the inquisitive qualities of the professional O.R. man.

We already have before us, with increasing frequency, examples of the way our chemical engineering technology is benefitting from the application—by non-O.R. men—of what might be called an *operations research attitude*. Ullock, in his recent *C.E.P.* articles, has shown us that the old concept of limitations of centrifugal pump performance is needless. Marshall, Lawrence, Brand, Murdock, Jacks, and others are doing likewise, but for different immediate purposes, demonstrating cause-effect relationships which are resulting in simpler specifications. Neidig, addressing the Los Angeles meeting, sought to make the chemical engineer aware of enlightened policies for appropriation of capital for process plant expansion, which resulted from cause-effect studies as to what really constitutes elements of risk.

There lies ahead a world of chemical engineering far from cut and dried. We are already unfolding challenges of a practical nature which doubtless can best be solved by men on location, whose senses are sharpened to read out of the environmental syndromes of their plants, markets, or human relations, conclusions of major importance.

J.B.M.

* Edward Goodrich Acheson (b. 1856), inventor of the electric furnace, discoverer of methods for producing silicon carbide, synthetic graphite, and colloidal graphite. An early associate of Edison, Acheson was vice-president of the A.I.Ch.E. 1908-10.

theory and practice of

CONTINUOUS PRESSURE FILTRATION

N. Nickolaus and D. A. Dahlstrom | The Eimco Corporation

Within recent years, continuous pressure filtration has experienced accelerated use in varied although specialized applications. Basically, this type of filter is similar to its counterpart, the rotary vacuum filter, with pressurized gas or air substituted for the atmosphere as the driving force. In addition, the filter cake and filtrate are generally discharged at or slightly above zero gauge pressure. Fabrication is accordingly more complex and expensive and certain mechanical alterations are necessary, due particularly to the discharge of the filter cake from the high pressure shell to atmospheric pressure. Because of higher cost, continuous pressure filtration finds application only where continuous vacuum filtration is inoperable, or where certain economies can be realized due to the peculiarity of the problem. Therefore, a fundamental understanding of the theory and operation of continuous pressure filtration is necessary in order to obtain not only optimum application, but also the most economical operating cost. When correctly applied, very appreciable advantages and savings will be experienced.

Where Pressure Filtration Is Used

Generally, the field of application can be reduced to five categories:

1. Vapor pressure of the liquid at the filter feed temperature is too high to permit the efficient use of vacuum.

To maintain a desired filtration rate with a continuous filter, a proper differential pressure must be applied across the filtering zone. However, with continuous vacuum filtration, the maximum possible pressure differential is limited to the atmospheric pressure minus the vapor pressure of the liquid. Accordingly, with volatile liquids and vacuum filtration, available pressure differential may seriously lower the filtration rate.

Added points to consider with vacuum filtration on volatile liquids are the requirement of a suitable condenser to minimize valuable product loss, attendant heat losses in the process, fractional vaporization where more than one liquid is present, crystallization of salts in the filter media which promotes blinding, and severe foaming with some organic liquids resulting in difficult pumping or entrainment losses. Continuous pressure filtration can eliminate all these disadvantages as well as provide any desired driving force to maximize filtration rates. Thus, it is finding its largest application in these cases.

2. Liquid viscosity is high (generally 100 centipoises or more) or solid particle size is small, necessitating a driving force greater than one atmosphere to obtain economic filtration rates.

The instantaneous rate of filtration per unit area for a particular feed slurry is a function of the ratio of the pressure differential and the product of liquid viscosity and the sum of cake and filter media resistances (*1*). In vacuum filtration, pressure differential is limited to a practical maximum of 25 to 27 in. Hg which may be insufficient to yield desirable rates and in some cases may not even "form" a suitable filter cake which can be efficiently "dewatered" in the drying portion of the cycle. Another consideration is that continuous pressure filtration will therefore permit a much higher operating temperature, which may reduce the viscosity of the slurry, flashing or lowering of pressure differential. The advantages of pressure filtration are magnified further as the plant elevation is increased, resulting in a lower atmospheric pressure for vacuum filtration.

3. Elimination of high labor costs due to certain batch filtration methods.

In many instances batch filters are replaced by continuous filters due entirely to the large labor savings and lower operating costs. The peculiarities of the problem or much greater filtration rates because of the increased driving force may justify the higher initial expense for the continuous pressure unit over the rotary vacuum filter.

4. Employment of a valuable or high temperature gas for the production of a dried cake product.

N. Nickolaus, formerly with The Eimco Corporation, New York, is now district sales manager, Byco Limited, New York. D. A. Dahlstrom is director of research and development, The Eimco Corporation, Palatine, Illinois.

Fig. 1. Pressure precoat filter.

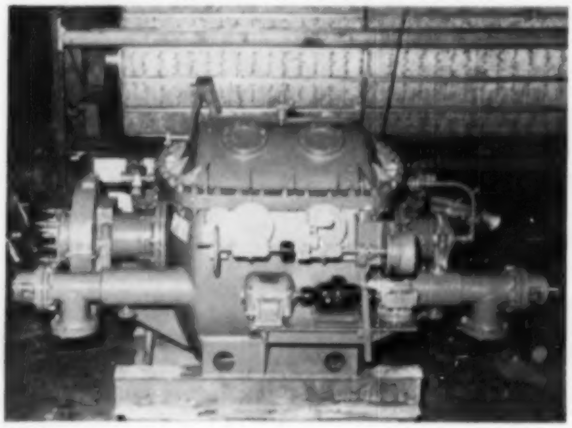
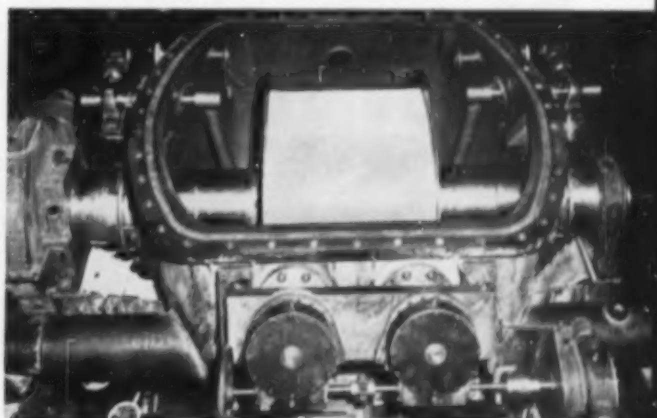


Fig. 2. Details of pressure precoat filter.



Stack or kiln gases, burned and scrubbed refinery gas, or by-product nitrogen from oxygen plants can be used to advantage as a gas supply. Many times the gas may be obtained under pressure so that little if any compression is necessary.

5. The filtration of hot saturated solutions which would exhibit excessive crystallization with a reduction in temperature.

In the handling of such liquids in a vacuum system, chilling through vaporization of solvent may cause crystallization within the filter. This may decrease capacity and require frequent shut-down for cleaning. Organic liquids which "set-up" with a reduction in temperature also come in this category. The continuous pressure unit is a practical solution in these cases.

Applications: Clarification and Dewatering

In a consideration of continuous pressure filters it would be well to distinguish between "clarification" or precoat filtration and dewatering, or so-called "cake" filtration (*2*). The removal of small amounts of solids to produce a clear filtrate is unlike the filtration of a high percentage of solids which will, in one complete drum cycle, produce an easily discharged filter cake.

The continuous pressure filter of either clarification or dewatering type consists of a rotating drum within a suitable pressure shell and is provided with a screw-advancing, cutting knife (Figure 1) for the precoat filter or an adjustable scraper blade for the cake filter. The horizontal drum is divided into shallow compartments (Figure 2) over which is placed the filter medium. Each compartment is connected to the valve end of the filter by independent pipe lines which terminate in a rotating pipe plate. A special filter valve of the sliding "face-to-face" type placed either outside or inside the pressure shell receives the filtrate and gas mixture and permits its passage to the filtrate receiver. The drum is driven by a variable speed drive through a totally enclosed worm wheel assembly on the filter trunnion. A pin-mounted, rake-type, slow-speed, oscillating agitator between the lower section of the drum and the filter tank maintains a uniform slurry suspension. In this type of filter the pressure shell normally serves as the filter tank.

CLARIFICATION, OR PRECOAT FILTRATION

The clarification-type continuous pressure filter employs a microscrew advancing, cutting knife. The advance of the cutting blade is variable and can be actuated either independently or through the filter drum drive.

On a rotating drum a precoat of diatomaceous earth or similar material is applied to a thickness of approximately 3 in. This precoat bed is the actual filtering medium and by the continuous removal of a thin layer of the precoat along the filtered solids, as the cutting knife advances, a clean filtering surface is always maintained. Thus slimy cakes and fine solids in small quantities are easily removed to produce clear filtrates at high flow rates.

The amount of precoat required to produce a 3-in. bed can be approximated by assuming 6 lb. of filter aid/sq.ft. of filter area. Consumption of precoat varies with each material, and will depend on the extent of penetration of solids into the bed. The general range of consumption is 0.5 lb./sq.ft./hr. for extremely difficult material to clarify down to 0.025 lb./sq.ft./hr. or less for well-defined crystalline material such as found in the specific application given by Figure 3.

The precoat filter station includes, besides the filter, a filtrate receiver, filtrate pump, a knock-out drum, cake discharge device, compressor, precoat tank, precoat pump, and gas make-up system.

A typical continuous precoat filter station is illustrated in Figure 3.

A 1 to 2% diatomaceous earth slurry is made up in the precoat tank using a clean liquid normally at the operating temperature of the filter. A low-speed agitator maintains the filter aid in suspension. The precoat slurry is pumped to the filter shell and by means of gas pressure maintained above the drum, the filter aid is gradually deposited on the rotating filter. The filtrate separates from the gaseous phase in the receiver and is returned by a pump to the precoat tank. The precoating period is normally about an hour but will vary with the type of precoat material used. After the 3-in. precoat has been formed, the filter tank is drained with a pressure differential maintained across the precoat and actual filtration follows.

The slurry to be filtered is fed to the pressure shell at an automatically controlled liquid level. The separated solids are shaved off the surface of the precoat by the advancing cutting knife. The solids are then removed from the pressure shell by means of a screw conveyer, which operates in either direction, to one of two pressurized cake receivers. These receivers are alternately sluiced down and their contents removed as slurry.

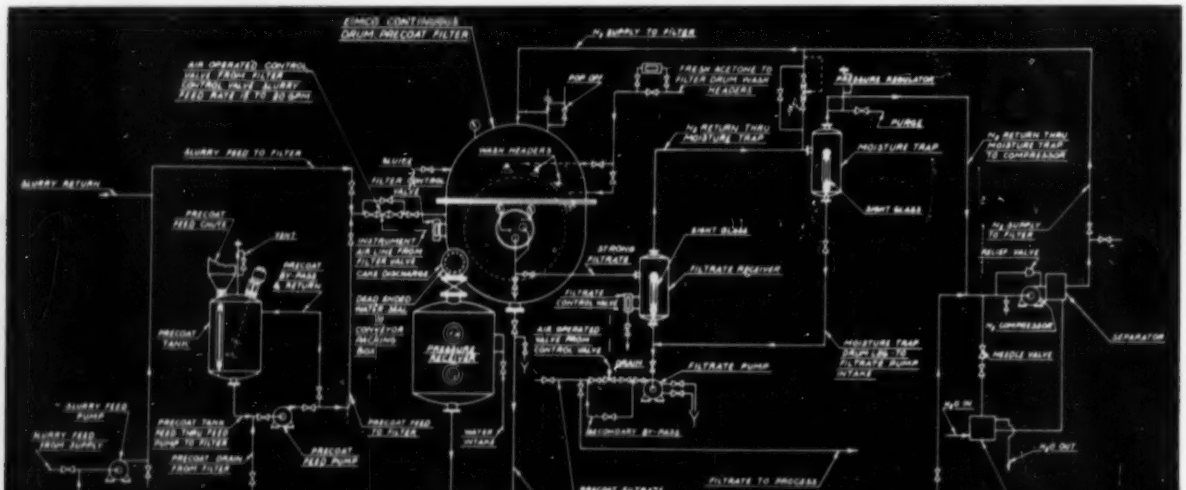


Fig. 3. Eimco continuous pressure precoat filter station flow sheet. Recycled nitrogen atmosphere, acetone, phenol, and fine solids slurry.

A knock-out drum is included to separate entrained liquid from the gas phase, thus minimizing build-up of this liquid in the compressor liquid sealing system. (A dry compressor would also require a separator to prevent carry-over of liquid to the compressor cylinders.) After compression the gas is returned to the filter shell. The wet compressor sealing liquid, normally a volatile liquid, is separated from the discharged gas and passed through a heat exchanger to remove the heat of compression before it is returned to the compressor. Gas make-up, introduced at the suction of the compressor, compensates for gas losses and maintains a constant level gas load. Regulating and control valves provide balanced pressure within the system. A similar system is presently being used to remove a crystalline insoluble salt from a mixture of toxic and volatile organic liquids. In order to prevent fouling of the reboiler in the distillation column, the salt is removed by pressure precoat filtration to produce a clean column feed.

In this particular installation the operating temperature is near the normal boiling point of the liquid phase with an operating pressure of 20-30 lb./sq.in. gauge. Nitrogen gas pressurizes the system to suppress the explosive qualities of the liquid. With continuous "in-place" washing of the precoat bed and solids being removed from the system, product recovery is practically 100%. Precoat life is from 5 to 8 days depending on certain physical qualities of the salt crystal which vary with plant operating conditions.

ADVANTAGES

The advantages of the continuous pressure precoat filtration system can be enumerated as follows:

1. high capacity
2. small floor space requirements
3. continuous operation
4. low precoat consumption
5. high product recoveries
6. low labor cost
7. isolation of toxic materials being handled and protection to operating personnel
8. clean operation.

Fig. 4 (above) details of drum construction.

Fig. 5 (below) inside of filter valve.

Although the equipment costs for this continuous system are higher than for batch filters, the advantages gained through continuous, automatic operation more than offset this higher first cost. It should also be noted that the outlay could be simplified where "once-through" compressed air can be substituted for an inert gas that must necessarily be recycled.

DEWATERING OR CAKE FILTRATION

In the handling of slurries containing higher percentages of cake-forming solids, a pressure drum filter is used. This filter differs from a precoat filter in that it does not have a microadvancing knife but rather a scraper blade, which operates in a fixed position after being adjusted for proper discharge. The formed cake is removed continuously from the drum by application of a gas blow directed to the individual compartments through the main valve which frees the cake from the filtering surface. The individual deck compartments are isolated from one another by longitudinal division strips into which the filter medium is caulked to provide a tight seal between sections. The medium is usually held in place by means of a uniformly spaced spiral winding wire (Figure 4). The filtration cycle is adjusted by proper bridging of the filter valve to provide variation in the time allowed for cake forming, cake washing, dewatering, cake discharge, and/or washing of the filter medium (Figure 5). Cake washing is simple and efficient, and auxiliaries such as a wash blanket or roller discharge to remove thin filter cakes can be used.

Hot gases may be used in pressure filter application to dewater and dry the filter cake. In a typical installation a top feed pressure drum filter handles a crystalline product where 550° F. stack gases are utilized.

The unit operates at 30 lb./sq.in.gauge. The dried solids are discharged by a fixed scraper blade and removed from the pressure shell with a screw conveyer operating under the same pressure as the filter shell. As the gas used is a waste gas product, recirculating is unnecessary.

Another installation uses pressure filters to remove spent catalyst from a volatile liquid product.

The filtration takes place at 10 lb./sq.in.gauge and at a high temperature. By-product nitrogen under pressure from an oxygen plant furnishes the driving force and serves to blanket all material in a noncombustion supporting atmosphere. This nitrogen is not recycled and is vented after filtration. The cake leaves the pressure shell by a screw conveyer into a partially filled level-controlled cake receiver for continuous cake discharge as a slurry.

Filter Design Considerations

The rotary filter, the pressure enclosure, and materials of construction are selected to meet the specific requirements of the material to be handled. The filters can be built to such specifications as API-ASME or ASME for Unfired Pressure Vessels with an extra allowance for corrosion. The tank or pressure vessel is designed as a cylindrical closure with dished heads having a flanged hood for easy access to the internal filter element. Rotation of the filter is provided by means of a variable speed drive, over a speed range determined by the nature of the material to be handled (generally 1 to 10 min./rev.). Observation ports and explosion-proof lights permit observation of the entire filter cycle. Cake washing headers and spray nozzles are located for proper washing of the cake as well as sluicing pipes and nozzles for cleaning of the filter and pressure shell. It is essential that the slurry level be maintained fairly constant and this is done by means of a level control device. Fluctuations in the liquid level on a fixed volume system will result in compression or expansion of the gas within the filter shell. This should be avoided, particularly in the case of a precoat filter, since such variation in pressure would disturb the precoat cake, cause cracking, and/or loss of part of the precoat bed.

ACCESSORY EQUIPMENT

For a continuous filter to function properly, careful consideration must be given to the selection of accessory equipment obtained from pilot plant or leaf test data. Normally the open-impeller type of **centrifugal pump** constructed of corrosion resistant materials is to be preferred. The basis for selection is capacity, total dynamic head surrounding the pump, and required net positive suction head (N.P.S.H.). Pump capacity is a function of the filter capacity under normal operating conditions. For the precoat filter, the filtrate pump must handle not only normal operation capacity but also the much higher capacity during the application of the precoat bed. In all cases the filtrate pump must not control filter capacity. To handle vola-

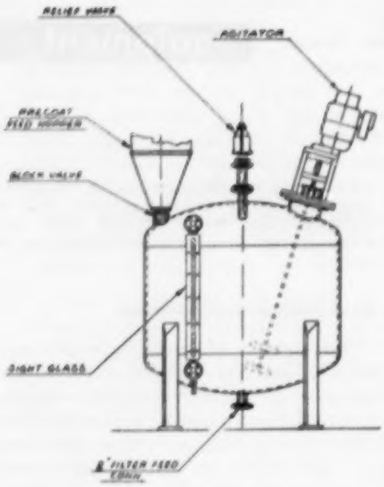


Fig. 6. Precoat preparation tank.
: 5 ft., 0 in. diam. × 5 ft., 0 in. long; 2 in. × 2 in. × 2 in. × 8-in. connections.

tile liquids, a pump must be selected with proper N.P.S.H. requirements to prevent flashing (*4*). Motors should have enclosures consistent with the operating atmosphere.

Filtrate receivers are normally vertical and of sufficient capacity to permit separation of the liquid from the gas. The gas velocity through the receiver is kept well below 10 ft./sec. The receiver volume below the feed inlet need not hold more than 3 min. of filtrate build-up.

Included with the receiver is a **level indicating and control device** to maintain constant volume and pressure conditions in the receiver and a liquid level sufficient to seal against loss of gas through the filtrate pump (*5, 6, 7, 8*).

The **knock-out drum** is a combination gravity and centrifugal entrainment separator. Gas from the filtrate receiver enters the bottom of the knock-out drum tangentially and impinges on the side wall. As the gas leaves through a tangential discharge near the top, it is free of entrained liquid. A connection is provided in the bottom to provide for removal of accumulated liquid by the filtrate pump (*5, 7*).

The **precoat slurry tank** is a vertical drum with dished heads and contains a slow-speed agitator (Figure 6). The tank size is determined by the liquid hold-up in the filter shell and the piping system. If the precoat liquid is valuable, its recovery is provided for by precoat tank storage or a return to the system. If volatile, a relief valve and vent line should be included as required. Feeding of the filter aid to the precoat tank is controlled as required. An alternate to the tank is an eductor, which should be preceded by a surge tank to hold liquid recycled from the filtrate receiver.

The **precoat slurry pump** can be a centrifugal or diaphragm type. Although filter aids are abrasive and some erosion can be expected, standard pumps are normally satisfactory because of infrequent and short pumping periods. Pump capacity will depend on the size of the filter and the average precoating rate. With intermediate sized filter aids a precoating rate of 60 gal./(hr.)/(sq. ft.) can be obtained or 90 gal./(hr.)/(sq.ft.) with the coarser grades of diatomites when using precoating liquors of water-like viscosities. With light oils the rate will be 35 gal./(hr.)/sq.ft.) The operating conditions for the pump will be determined by precoating capacity, N.P.S.H. requirements, and total dynamic head (T.D.H.) requirements. In calculating head conditions account must be taken of the filter shell operating pressure.

The **gas compressor** can be either the wet or dry type with both having specific advantages depending on the application. The former will require fewer precautions against liquid carry-over in a recycling system and will usually exhibit lower maintenance costs. The dry-type compressor will generally require less horsepower particularly where high temperature, volatile liquids, or high pressures are involved. Both types must be installed with proper heat exchangers to remove excess heat of compression whenever temperature must be controlled below compressor discharge temperature or a recycle gas system is employed.

It should be emphasized that positive and accurate temperature control on the entire filter station can be achieved by employing the shell temperature as intelligence for automatic control of the cooling water through the after-cooler or heat exchanger. The gas compressor size depends on the volume of gas handled to maintain the required pressure differential and the operating pressure level. Pressure on the suction side of the compressor should be maintained slightly above atmospheric to prevent infiltration of air when an inert recycled atmosphere is required in the system. The compressor accounts for the largest horsepower consumption in the continuous filter station and proper flow sheet design should be used to minimize this energy requirement. Where difficult filtration slurries are encountered, gas capacity will generally be in the range of 1-2 cu.ft./min./sq.ft. measured at compressor suction conditions. With more permeable cakes, where it is still desirable to operate at high pressure differentials across the cake formation phase of the filtration cycle to maximize filtration rate, gas rate through the cake is reduced by automatically back-pressuring the cake-drying phase. By this method the compressor requirements can normally be limited to a maximum of 3 cu.ft./min./sq.ft. measured at compressor suction conditions. Further economies can be obtained by using a separate compressor to take suction at a pressure equal to the back-pressure at the cake-drying phase of the filter cycle.

When blow-back gas is needed to discharge the filter cake, it must be supplied at a pressure of 2-5 lb./sq.in. higher than the shell pressure. The quantity of gas will be 0.25-0.5 cu.ft./min./sq.ft. It is generally most economical to use the main compressor for supplying this volume by use of automatic control of back-pressure on the compressor discharge. This gas is also reused as a part of the total gas required as driving force for filtration and cake dewatering and thus will not increase compressor capacity demand.

Cake discharge from the pressure system can be either wet or dry. The former is preferred from both operational simplicity and initial cost. The cake is merely repulped with water and the resultant slurry discharged through an automatic level control valve. Thus liquid seal is maintained at this point to prevent any loss of pressurized gas. Where a dry cake discharge is necessary, two pressure cake receivers in conjunction with a reversible screw conveyer are generally employed. Thus, when one receiver is full, the screw conveyer is reversed to the other receiver and the full unit isolated from the pressure system. Where valuable inert gases are involved, the receiver can be depressurized by bleeding the compressed gas back to the suction side of the compressor. When at atmospheric pressure, the receiver is then discharged manually or by use of a small screw conveyer at the base of the unit. The dry cake can be discharged without any manual labor or direct attention by use of a time-cycle control system. With certain types of solids that lend themselves to special conveyer methods, it is possible to obtain a continuous dry cake discharge from the pressure system to the atmosphere.

The **gas system,** the function of which is to maintain equilibrium conditions, should be designed to permit both automatic and manual control. The latter is used when starting up the filter or for emergency purposes. A pressure control valve by-passing the filter and delivering to the compressor suction removes any danger of excessive pressure and facilitates manual control. In addition, an automatic make-up gas system should be installed where recycling of inert gases is used. As the gas loss is limited to the low leakage through stuffing boxes and packing glands,

standard compressed gas cylinders can be employed. A simple regulator similar to a welding gas regulator is employed on the cylinder and set to maintain the desired minimum compressor suction pressure. Make-up gas is generally limited to one standard compressed gas cylinder for two to seven days of operation.

It should be emphasized that the flow sheet can be instrumented to obtain complete **automatic control.** Each application must be carefully studied to determine the optimum control systems to maintain temperature, pressure, liquid and slurry levels, feed rates, and cake and filtrate discharge at desired operating points automatically. As the control methods are closely related to horsepower requirements, the optimum automatic control flow sheet will also minimize operating costs.

Piping must be selected so as to minimize pressure drops and frictional losses. Plugging of lines can be avoided by eliminating horizontal sections of pipe, and it is well to provide flushing connections at danger points.

Theory

Since filtration does not follow theoretical and empirical formulas to the same degree as other unit operations, it is always desirable to run pilot plant tests on any new material to obtain complete data as a basis for design of the filter station. When this cannot be done, a filtration leaf testing procedure can be instituted which if performed in sufficient detail will permit a dependable scale-up to the production flow sheet. As the filtration problem increases in complexity, the pilot plant testing method is preferable. A detailed report on pilot plant and leaf filtration testing procedure has been prepared and will serve as an excellent guide for this program.

INFORMATION NEEDED

The design information developed from such test work should include the following:

1. size and type of rotary pressure filter required
2. optimum operating temperature and pressure
3. gas flow rate or compressor size
4. filter-aid or precoat consumption where applicable
5. type of filter media
6. filter cake moisture content

In order to understand the importance of each of the above factors, an individual discussion is warranted.

INFLUENCE OF PRESSURE ON FILTRATION RATES

One of the first variables that should be investigated in the testing program for continuous pressure filtration is the **influence of pressure drop upon filtration rate.** If the percentage increase in rate with an increase in pressure drop is relatively small, it would generally be more economical to operate at about 20 lb./sq.in. gauge on the shell side. If rates continue to increase with pressure at a sufficient rate, operating pressures of 40 to 60 lb./sq.in. gauge or higher can be employed at a reduction in filter area requirements and operating costs per unit of production.

Figure 7 is a log-log plot of **filtrate rate** in gal./(hr.)/(sq.ft.) as a function of pressure drop for five different materials. All these slurries could not be handled by vacuum filters because of liquid volatility, uneconomical rates, or insufficient driving force due to high viscosity.

The modified Poiseuille equation serves as an excellent guide for analysis of Figure 7 (*16*).

$$\frac{dV}{Ad\theta} = \frac{(\Delta P)}{\mu\left[\dfrac{\alpha(\Delta P)^s wV}{A} + r\right]} \qquad (1)$$

Assuming that the resistance of filter media, lines, etc., is negligible, the equation can be integrated for the constant pressure condition.

$$\frac{V^2}{A^2} = \frac{2(\Delta P)^{1-s}\theta}{\mu\alpha w} \qquad (2)$$

The time θ refers to the form time which can be related to the cycle time as follows:

$$\theta = B\theta_c \qquad (3)$$

Substituting for form time and taking the square root of both sides of the equations:

$$\frac{V}{A} = \left[\frac{2B(\Delta P)^{1-s}\theta_c}{\mu\alpha w}\right]^{1/2} \qquad (4)$$

Finally, the equation can be converted to the conventional units for continuous filtration of volume/hr./unit area by multiplying both sides of the equation by $60/\theta_c$ if θ_c is in units of minutes.

$$Z = \left[\frac{7200\ B(\Delta P)^{1-s}}{w\mu\alpha\theta_c}\right]^{1/2} \qquad (5)$$

Referring again to Figure 7, one will note that a relatively good straight line agreement was obtained on all material. In the five slurries cited, the terms B, θ_c, and w have been maintained constant. For the incompressible ideal cake, the compressibility coefficient s equals zero and a plot similar to Figure 7 should exhibit a slope of 0.50.

Four of the slopes of the parameters of Figure 7 ranged from 0.445 to 0.6, indicating a close agreement to the ideal condition of a noncompressible cake. The fifth parameter exhibited a slope of 0.90. As the solids in the filter cake become more compressible, the slope of the log-log plot of Figure 7 should approach zero. The explanation of those parameters possessing slopes greater than 0.5 is believed to be in the factors of filtrate viscosity and driving force. Sufficient driving force must be applied properly to form a filter cake. As filtrate viscosity increases, required driving force for this condition increases. The fine-grind Irish Moss extract which has a slope of 0.90 was very viscous with a filtrate viscosity of 422 centipoises. The remaining parameters with slopes above 0.5 also exhibited high filtrate viscosities of 100 centipoises or better. Further substantiation of this hypothesis is found in the shape of the parameter for Torulopsis Utilis Yeast at low pressures. It will be noted that the curve fell off sharply below 15 lb./sq.in. pressure drop. The curve in this region exhibits slopes of greater than 0.5 although above 15 lb./sq.in. a consistent slope of 0.44 was established. As the yeast slurry is difficult to filter due to the 3 to 8 μ particle size of the yeast cells, it would appear that a driving force of about 15 lb./sq.in. is necessary to initiate proper filtration.

The results of Figure 7 illustrate one of the major advantages of continuous pressure filtration. All five slurries tested could not be handled by vacuum filtration as rates were too low and filter cakes too thin and moist for proper operation. However, by employing larger driving forces, economic rates could be obtained with a resultant dry and dischargeable cake. Furthermore, although the solids were of a type that were thought to be compressible,

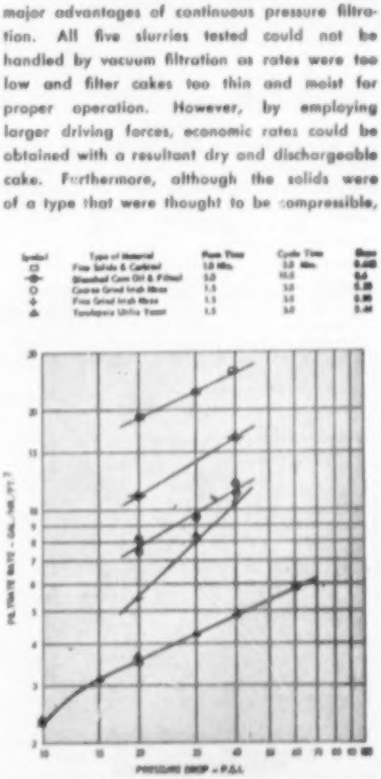


Fig. 7. Continuous pressure filtrate rate as a function of pressure drop. Data from 0.1 sq.ft. leaf tests.

Table 1.—Filtrate Rates for Crystallized Sodium Chloride and Quaternary Salt

3-min. cycle—50% submergence—30 lb./sq.in. pressure drop

temperature—° F.	filtrate rate—gal./(hr.)/(sq.ft.)
118	25.8
131	62.3
151	120.0

Table 2.—Cake Moisture Content of Torulopsis Utilis Yeast

Continuous Pressure Filtration

pressure drop lb./sq.in.	avg. cake moisture wt. %
10	77.1
20	75.7
30	74.1
40	74.3
60	72.0

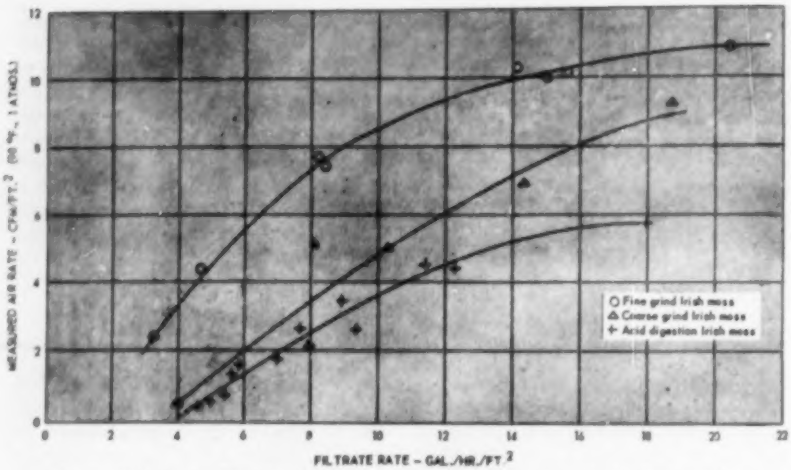


Fig. 9. Air rate as a function of filtrate rate—Irish Moss extracts. Basis: 3-min. cycle, 50% submergence, 40 lb./sq.in. gauge.

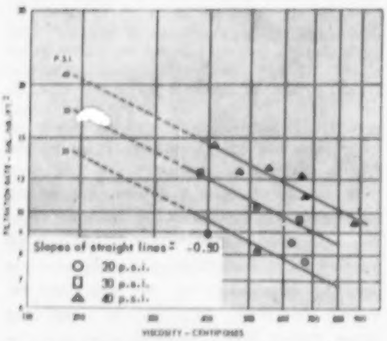


Fig. 8. Filtrate rate as a function of filtrate viscosity—parameters of pressure drop; coarse grind Irish Moss extract. Basis: 3-min. cycle, 50% submergence, 1.5 lb. Dicalite 4,200/lb. moss, Orlon 540 filter media.

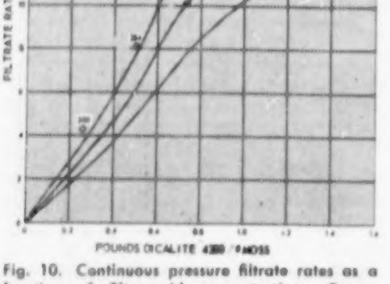


Fig. 10. Continuous pressure filtrate rates as a function of filter aid concentration. Coarse grind Irish Moss.

experimental data indicated that sufficient driving force would establish a relatively noncompressible cake.

INFLUENCE OF VISCOSITY AND TEMPERATURE ON FILTRATION RATES

With reference to Equation (5), filtration rate should be proportional to the −0.5 power of filtrate viscosity. Figure 8 is a log-log plot of filtrate rate in gal./(hr.)/(sq.ft.) as a function of viscosity with parameters of pressure drop for coarse grind Irish Moss extract. The best lines of slope −0.5 have been drawn for the three sets of data points and a good agreement was obtained, particularly at the higher pressure drops. Similar results were obtained in other test work indicating the validity of the theoretical equation.

Figure 8 emphasizes an important advantage of pressure over vacuum filtration. The former method permits higher temperature operation without danger of flashing or excessive vaporization. Thus reduced liquid viscosities can be achieved particularly with high viscosity organic compounds, and filtration rates are increased by this factor as well as by the higher driving forces obtainable. A striking example of this is contained in Table 1. A crystallized sodium chloride had to be removed from a quaternary salt and carrying solvent. At about 90° F., the liquid "sets-up" indicating a probable severe change in viscosity with temperature. Leaf tests were run at three different temperatures, as indicated in Table 1.

Vacuum filtration would entail the employment of 100° F. temperatures in order to eliminate severe foaming, prevent solvent vaporization, and provide sufficient driving force. As plant temperatures will average 175° F., continuous pressure filtration has a very pronounced advantage.

Sizing of Compressor for Continuous Pressure Filtration

Next to the filter itself, the compressor required to furnish the driving force for filtration will entail the second largest capital investment. Because of the larger driving force, gas displacement expressed as standard cu.ft./min./sq.ft. of filtration area is naturally going to be greater than with continuous vacuum filtration. Therefore, any testing program should include measurement of required gas displacement to minimize this important investment. A convenient graphical method for expressing gas displacement is illustrated in Figure 9. Measured air rate (std. cu.ft./min./sq.ft.) is plotted as a function of filtrate rate for three different types of Irish Moss extracts at constant pressure drop, cycle time, and submergence. The variation in filtrate rate was obtained through changes in viscosity and filter aid concentration. The filtrate rate is actually an expression for permeability of the filter cake under the conditions stipulated. Thus, permeability increases with filtrate rate and the correlation is therefore to be expected. It should be stressed, however, that if cycle time and submergence are changed, the correlation will not necessarily apply. It is also noted that where gas rate through the cake would be excessive at full pressure drop needed for cake formation, it can be reduced to the minimum required for desired cake moisture by proper back-pressuring as indicated earlier.

Determination of Precoat and Filter Aid Requirements

Whereas precoat requirements can be accurately determined by pilot plant testing, leaf tests do not offer the same precision. As precoat life is a function

of the thickness of cut and must be made on each revolution of the filter, it is obvious that it will be impossible to shave manually the test leaf to an accuracy of a thousandth of an inch necessary for this determination. Rather, observation and experience with continuous pressure leaf tests must be relied upon as an estimation.

When filter aid must be charged directly to the feed slurry in order to obtain a filterable material, a test program should be initiated to determine the minimum concentration required. As continuous filtration results in thinner filter cakes than batch pressure filtration, appreciable savings in filter aid can be achieved if the slurry is amenable to this type of operation. Figure 10 is a plot of filtrate rate in gal./(hr.)/(sq.ft) as a function of filter aid concentration with parameters of filtrate viscosity for coarse-grind Irish Moss extracts. Pressure drop is 40 lb./sq.in. with a 3-min. cycle and 50% submergence.

Irish Moss upon digestion in water at 205° F. turns to gelatinous slimy solid particles which cannot be filtered without filter aids. This condition plus the high viscosity of the extract results in large filter aid concentrations when processed in batch pressure filters. A leaf testing program was initiated to ascertain filter aid savings with continuous pressure filtration. The first tests were performed on extracts ranging in liquid viscosity from 400 to 870 centipoise viscosity. As operating viscosity averaged 200 centipoises, prediction of rates at lower viscosities were obtained by multiplying the test rate by the square root of the test viscosity divided by the full-scale operating viscosity as discussed earlier. The smooth curves of Figure 10 give these predictions for viscosities of 200, 300, and 500 centipoises. Later confirming tests were made at viscosities approaching 200 centipoises. The data points with corresponding viscosities are indicated in Figure 10 and a reasonable agreement was obtained with predicted results. A filtration rate of 8 gal./hr./sq.ft. was desired at 200 centipoises viscosity with the result that only 0.5 lb. of Dicalite 4200/lb. of Irish Moss was required. With batch filtration, filter aid requirement was 2.11 lb. of Dicalite 4200/lb. of Irish Moss or a saving of 76.3% in filter aid consumption.

Filter Cake Moisture Content

In many cases, moisture content in the filter cake will be a governing factor. This is particularly true where the filtrate is the valuable product, the cake must be dried, or cake washing must be performed.

In earlier papers, it was shown that cake moisture per cent for a solid material is a function of the correlating factor (*17, 18, 19*).

Cake moisture correlating factor

$$= \left(\frac{\text{cu.ft./min.}}{A}\right)\left(\frac{\Delta P}{L}\right)(\theta_d)\left(\frac{1}{\mu}\right)$$

As the correlating factor increases, cake moisture content asymptotically approaches a minimum value. Thus, it will be observed that the greater values of cu.ft./min./A and ΔP obtained by continuous pressure filtration will contribute towards a lower moisture content. As this type of filtration permits higher operating temperatures and thus lower filtrate viscosities, additional reductions in cake moisture will be experienced.

As an example of the decrease in moisture content with an increase in pressure drop, results observed on Torulopsis Utilis Yeast slurry are given in Table 2. As the yeast cell is composed primarily of water, the reduction in surface moisture is considerably greater than indicated above.

Filter Media Selection

The selection of proper filter media is extremely important to the success of continuous pressure filtration. Three factors are of primary significance:

1. the filter media should give maximum filtration rate consistent with desired filtrate clarity
2. the filter media must not blind-off with time
3. maximum cloth life should be obtained.

Downtime for changing filter cloth will be longer than with continuous vacuum filters as the piping connections and shell head must be removed and reinstalled. In this regard, the third criterion is particularly important where high temperatures are encountered. There is a large variety of synthetic and woven wire media that should be given serious consideration in all continuous pressure filtration. It should be emphasized that significant increases in filtration rates and reduction in operating costs can be experienced by employment of the optimum media.

Notation

- A = filtration area
- B = submergence or fraction of cycle time used for form time
- L = cake thickness
- r = resistance of filter media, lines, etc.
- s = filter cake compressibility exponent
- V = volume of filtrate collected
- w = wt. of dry cake solids per unit volume of filtrate

GREEK LETTERS

- α = specific cake resistance at $\Delta P = 1.0$
- ΔP = pressure drop
- θ = time of filtration
- θ_c = cycle time
- θ_d = drying time
- μ = filtrate viscosity

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Recovery of ethylene glycol of low acidity from spent antifreeze solutions has been accomplished through a process embodying continuous vacuum distillation of a feed stock that has been excessively neutralized with solid sodium hydroxide. The novelty of this process lies in the fact that, unless excessive neutralization of the feed stock is employed, the resulting ethylene glycol distillate product will be highly acidic and consequently corrosive for use as a heat transfer medium.

RECOVERY OF ETHYLENE GLYCOL from spent antifreeze solutions

M. B. Glaser and George Thodos

Northwestern Technological Institute
Evanston, Illinois

The use over extended periods of time of individual lots of ethylene glycol as a heat transfer medium for the removal of heat from internal combustion engines and other industrial heat transfer operations is discouraged through the gradual fall-off of protection supplied by the inhibitors present in the commercial product, resulting in the oxidation of the glycol to corrosive acids. The mechanism of oxidation of ethylene glycol under such circumstances is believed to take place as shown in Figure 1.

No process for the recovery of ethylene glycol from spent antifreeze solutions is in commercial use today.

Several processes for the recovery of glycols from aqueous solutions are presented in the patent literature (*2, 6, 7*). The Ruys process (*6*) deals with the recovery of polyhydric alcohols such as ethylene glycol from dissolved salts by subjecting the aqueous glycol solution to flash vaporization in the presence of a circulating body of oil. In this process the alcohol boils off at a lower temperature, leaving the salts in suspension in the oil. Fisher's process (*2*) employs distillation in the presence of a hydrocarbon agent that is later separated and reused.

The final purification steps in the commercial production of ethylene glycol involve vacuum distillation in order to prevent decomposition and oxidation that would occur if ethylene glycol were distilled at its normal boiling point (398° F.). Following these lines of approach Gallup (*3*), by a series of laboratory vacuum distillation studies, which included neutralization of the feed charge with amounts of solid sodium hydroxide, including theoretical requirements, produced from spent antifreeze solutions ethylene glycol fractions which were as acidic as the original feed stocks. Extending this work, Hansen (*4*) used a gas-fired batch still handling 3.3 gal. feed/hr. In this work Hansen exceeded the theoretical sodium hydroxide requirements by 25%, but the product resulting from distillation at 15 mm. Hg (abs.) was acidic.

Vacuum Distillation Process

A successful process has been developed which produces a distillate ethylene glycol product representing an acid reduction of 99.8%.

A simplified flow diagram of this process appears in Figure 2. The basic unit consisted of an unlagged Olson Superflow continuous still without plates, constructed from ordinary steel. This still has a rated capacity of 50-75 gal./hr., based on the distillation of low boiling naphthas for which the still was primarily designed. Heat was supplied by steam to a number of tubes located in the bottom of the still. Adequate instrumentation was provided to measure all process variables.

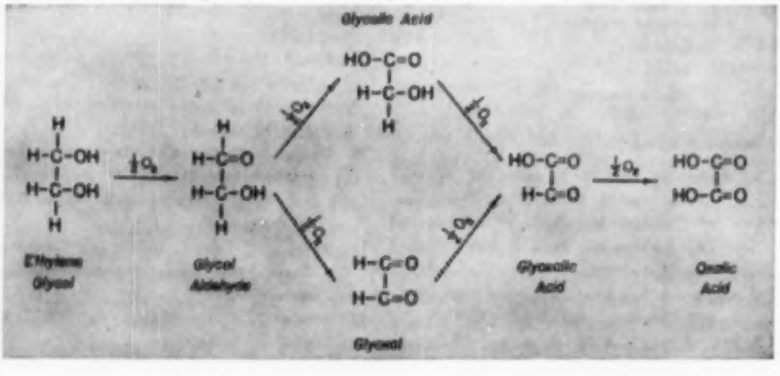
The still was fed from a 125-gal. feed tank by vacuum through a Simplex constant level feeder attached to the still. (The feed was heated by heat exchange with the overhead vapors in the feed preheater before entering the still.) Vapors were continuously removed by vacuum, passed through the preheater, and then were totally condensed in a vertical, water-cooled shell-and-tube condenser. Two 125-gal. tanks were connected to the condensate line for collecting distillates of water and ethylene glycol, respectively. Vacuum was supplied by a twin element, two-stage steam ejector with an intercooler connected in series and a single-stage high pressure (160 lb./sq.in. gauge) steam ejector, all coupled to a single barometric condenser.

FEED STOCK

Large quantities of contaminated feed stock were prepared according to the procedure developed in the oxidation studies described below.

The problem of obtaining large quantities of feed stock of oxidized ethylene glycol solutions

Fig. 1. Reactions involving the oxidation of ethylene glycol to oxalic acid.



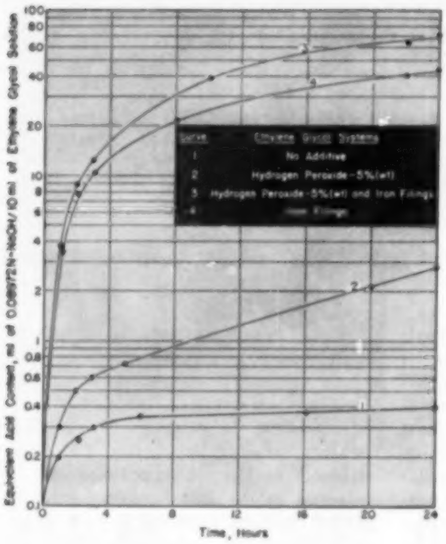
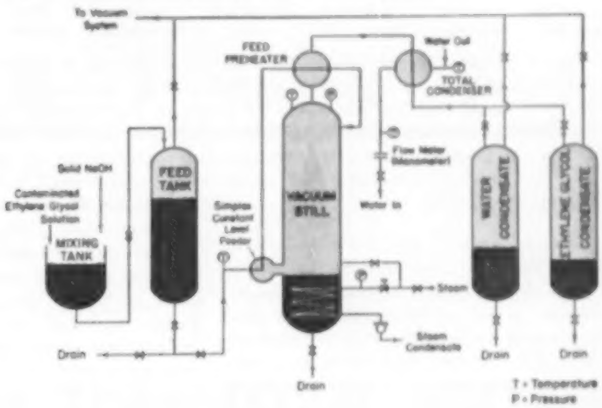


Fig. 3. Relative oxidation studies of ethylene glycol with various oxidizing agents.

Fig. 2. Schematic diagram of distillation equipment.



necessitated the development of a method capable of producing acidified ethylene glycol which, when proportioned with water, produced a feed stock whose acidity was comparable to that of a highly contaminated antifreeze solution. The apparatus for oxidizing ethylene glycol consisted of a 500-ml. flask externally heated with an electric heater into which air was bubbled continuously through glass tubing extending below the liquid level. The ethylene glycol solution was maintained at temperatures of 270-300° F. To the ethylene glycol solution were added various substances to hasten the rate of oxidation. These oxidation tests consisted of processing the following types of ethylene glycol solutions:

1. pure ethylene glycol
2. a solution of ethylene glycol containing 5% by weight of hydrogen peroxide
3. a solution of ethylene glycol containing 5% by weight of hydrogen peroxide in contact with iron filings
4. ethylene glycol and iron filings

Each system was systematically studied by sampling at periodic intervals and neutralizing each sample with a 0.08972N sodium hydroxide solution in which thymolphthalein was used as the indicator. Thymolphthalein exhibits a sharp color change from colorless to blue in the pH range of 9.2 to 9.6 (5). This pH range was established by Hansen (4) as the neutralization point for ethylene glycol with the use of a line operated McBeth pH meter equipped with glass electrodes. The yellowish color of oxidized glycol solutions did not interfere with the blue color resulting from thymolphthalein at the neutralization point. Other indicators suitable in this pH range were not found to exhibit a clear color change in the yellow solution.

Besides the acids produced as a result of oxidation, a relatively small amount of aldehydes is also formed. This amount is usually less than 10% of the acid concentration. Hansen (4) attempted to analyze these aldehydes, but found that even the most accurate analytical methods gave unreliable results. This was due to the highly unstable nature of the aldehydes present in the oxidized solutions. Therefore, in this investigation, no attempts were made to analyze for aldehydes and only the acid content of the ethylene glycol solutions was considered.

Results of the relative oxidizing action of the various reagents are presented in Figure 3 as a function of time of reaction. A review of the results of this oxidation study shows that the presence of iron filings in ethylene glycol solutions enhances oxidation to a much greater extent than that exhibited for the other cases. The presence of iron filings in hot glycol solutions produces a hundred fold increase in the amount of oxidation over that resulting from the use of air alone after a 24-hr. test, and a fifteen fold increase over the combination of ethylene glycol and hydrogen peroxide. Therefore, the presence of iron greatly enhances the oxidation potentialities of antifreeze solutions in automobile radiator systems. It is reasonable to expect that antifreeze solutions in automobile cooling systems are not subjected to such rapid and rigorous reactions since the average radiator temperatures seldom exceed 175° F. and the available iron surface per volume of solution would not be so extensive as that employed in these tests.

Table 1.—Operating Conditions for Removal of Water from Dilute Ethylene Glycol Feed Stocks

	Still			Steam		Material Balance, lb.					Composition, Wt. % Ethylene Glycol			
	pressure	overhead	distillation rate	pressure	rate		water distillate		kettle			water distillate		kettle
run no.	mm. Hg	temp., ° F.	lb.(H_2O)/ min.	lb./sq. in. abs.	lb./min.	feed	continuous	batch-wise	residue	losses	feed	continuous	batch-wise	residue
1	96.6	125	2.91	18.4	3.49	685	549	66	55	15	15	2	44	99
2	91.0	120	2.07	22.7	3.33	805	568	86	66	85	22	4	68	99
3	116	140	2.29	19.0	3.63	653	511	81	35	26	14	4.5	14	99
4	175	151	2.40	18.2	3.60	582	436	92	45	9	13	2	21	99
5	149	145	2.18	26.9	4.00	166	127	15	16.4	7.6	15	2	10	99
6	81.0	115	1.91	35.7	3.56	373	166	80	81	46	43	4	50	99

Table 2.—Operating Conditions for Continuous Distillation of Ethylene Glycol from Contaminated Ethylene Glycol Concentrates

	Still			Steam		Material Balance, lb.				
run no.	pressure mm. Hg	overhead temp., °F.	distillation rate lb.(glycol) /min.	pressure lb./sq.in.abs.	rate lb./min.	feed	distillate	residue	losses	ethylene glycol content of distillate
7	24	235	0.85	59	4.79	395	300	81	14	99.5
8	33	242	0.58	61	4.65	306	203	75	28	99.5
9	26	237	0.73	59	4.82	353	258	71	24	99.5

PROCESS OPERATION

To the prepared feed stock, designated quantities of solid sodium hydroxide were added in order to establish the influence of sodium hydroxide on the acid content of the final ethylene glycol product. The treated feed stock was subjected to distillation for the continuous removal of water as overhead product and the intermittent withdrawal of contaminated ethylene glycol concentrates. After sufficient glycol concentrates were accumulated, this material was distilled for the continuous removal of ethylene glycol as overhead product and for the collection of contaminated residue as kettle product. Samples of the feed and final product were analyzed for acid content by titrating with a standard sodium hydroxide solution, and the ethylene glycol contents were accounted for by specific gravity measurements.

The total quantities of feed processed for the removal of water varied from 166 to 805 lb. and required a processing time that varied from 1 to 4.6 hr. The feed compositions varied from 13 to 43 wt. % ethylene glycol. Satisfactory distillation rates of water were obtained at still pressures below 175 mm. Hg. Altogether six runs were made that involved the continuous removal of water. Results of these runs are presented in Table 1.

The ethylene glycol concentrates were subjected to a continuous vacuum distillation for the recovery of ethylene glycol as overhead distillate. (Table 2). Because of the low vapor pressure of ethylene glycol, this distillation procedure required pressures below 40 mm. Hg with steam available at 61 lb./sq.in. gauge for heating purposes. Although higher steam pressures would increase the rate of ethylene glycol distiliation, this advantage would prove detrimental to the process since the higher temperatures resulting in the kettle would tend to favor both oxidation and decomposition of the ethylene glycol. In view of these limitations, absolute pressures below 40 mm. Hg were employed for the more efficient operation of the process. When the absolute still pressure was increased to 40 mm. Hg. no distillation of ethylene glycol took place and, consequently, for the unlagged equipment used in this investigation this pressure was considered limiting. Since considerable heat losses occurred during the distillation of ethylene glycol, the rates of distillation were correspondingly lower. Limitations on both the equipment and the vacuum system made it impossible to operate at still pressures below 24 mm. Hg.

PURITY OF DISTILLATE PRODUCT

Specific gravity determinations on the ethylene glycol distillate product indicated contents for this compound of 99.5%. Titrations with 0.08972 N-NaOH solution by the use of thymolphthalein as an indicator established a sodium hydroxide equivalent normality for pure ethylene glycol of 0.000915. Similarly, the acid contents of the untreated feed stocks were determined and found to range from 0.0532 to 0.0715. When these feed stocks were neutralized with an excess of sodium hydroxide, ethylene glycol distillates were produced whose acid concentrations approached the normality of pure commercial ethylene glycol. The acid contents of feed stocks used and distillate products produced are presented in Table 3 along with the extent of feed neutralization employed in each case. For the three runs, the acid reduction based on the original feed was 99% or better. In the similar work of Hansen (*4*), in which theoretical sodium hydroxide requirements up to 125% were used, the maximum acid reduction amounted to 92%. In this work, for the comparable conditions represented by run 7 (Table 3), the acid reduction became 99.3%. The presence of considerable amounts of acid in the ethylene glycol distillate product obtained by Hansen (*4*) is attributed to the decomposition of the material in the still resulting from localized heating produced in the externally fired still; whereas in this work this difficulty was avoided by using steam as the heating medium.

From the foregoing results, it is reasonable to expect that the ethylene glycol product resulting from the distillation of an acid feed stock employing 50-75% excess solid sodium hydroxide as a neutralizing agent would be suitable when properly inhibited for use as a permanent antifreeze solution.

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Presented at A.I.Ch.E. meeting, Louisville, Kentucky.

Table 3.—Acid Contents of Feed Stocks and Ethylene Glycol Distillates

runs	Acid normality of feed stock	g. NaOH Added /g. ethylene glycol in feed	Percent of theoretical neutralization	Acid normality of ethylene glycol product	Percent acid reduction
7	0.0715	0.0327	125	0.00123	99.3
8	0.0532	0.0292	150	0.00131	99.0
9	0.0621	0.0397	175	0.00105	99.4

The acid normality of pure commercial ethylene glycol is 0.000915.

Two of four in-line Chemico reforming heaters producing hydrogen in the latest ammonia plant of Lion Oil Co.

New Methods of HEATER DESIGN

This study is primarily a first step in the development of a method of evaluating the performance of the radiant combustion sections of fuel-fired heaters and boilers. Such a method should be useful both as a means for designing new equipment and for comparing the operating performance of different furnace designs on an equitable basis.

L. J. McCarthy

Chemical Construction Corp.
New York, N. Y.

RADIANT DESIGN OF HIGH TEMPERATURE HEATERS and . . . The Chemico Heater

Fuel-fired heaters of various types, including high temperature reaction heaters, refinery heaters, and steam boilers are, and will continue, as an important element in much of our chemical plant and industrial construction. Most fuel-fired heaters and boilers include a radiant combustion chamber in which the fuel is burned and in which a substantial portion of the heat released in the chamber is transferred to the absorbing surface by direct radiation.

Relatively few publications have presented actual performance data on the radiant heat transfer obtained in commercial units and it is only within recent years that accurate data have been published on the performance of the radiant boiler furnace sections of central station boilers. One of the reasons for this, no doubt, at least in the case of central station boilers, is the extreme complexity of making a carefully conducted test and isolating the performance of the radiant section from the balance of the unit.

In the present paper one specific type of high temperature radiant heater (the Chemico Reforming Heater) is described and its unique features are discussed in some detail. Original performance data on several Chemico heaters are presented together with an equation which correlates the radiant heat transfer with the important variables.

It is shown that the same general type of equation is applicable to the radiant sections of refinery-type heaters and steam boilers and that the constants in the equation vary with the geometrical arrangement of the furnace enclosure, heating surface and burners.

Specific equations are developed for a number of different furnace types on which performance data are available and the performance of the different furnace types is compared.

Data covering pages 15-23 of manuscript, Table 5-8, and Figures 9-13A are on file (Document 4791) with A.D.I. Auxiliary Publications Project, Library of Congress, Washington, D. C. Obtainable by remitting $2.00 for microfilm and $3.75 for photoprints.

Description of Chemico Reforming Heater

The Chemico reforming heater was developed specifically for the high temperature conversion of hydrocarbons and steam to hydrogen. This operation requires the passage of a mixture of the two materials over a catalyst contained in heated tubes wherein the so-called methane-steam reaction takes place. The reaction is highly endothermic and heat required for the reaction is considerably greater than the sensible heat required to raise the temperature of the mixture.

An isometric view of this heater is shown in Figure 1.

It consists of a vertical, cylindrical steel shell lined with suitable refractory.

The heat absorbing tubes are arranged to hang vertically in what are essentially four banks or rows radiating from the center of the heater to the circumference. This serves to divide the combustion and radiant chamber into four identical radiant-combustion zones.

The burners are arranged in the floor of the heater and fire vertically upward. With a group of burners in each of the four radiant sections, the heat is radiated directly to both sides of the tubes and to the refractory wall which reradiates to the tube banks.

The flue gases travel vertically upward, parallel to and on both sides of the tubes to the top of the radiant chamber at which point they enter a refractory collecting duct which is arranged in the form of a cross and through which the upper ends of the heating tubes project. This cruciform duct serves to bring the flue gases into closer contact with the tubes at their upper ends and one leg of the cross serves as an outlet flue through which the flue gases are conducted from the heater.

A view of an individual tube is shown in Figure 2.

The fluid being heated enters the tube at its upper end through nozzle A, flows downward through the catalyst to point B, the lower end of the tube adjacent to the burners. During this time it is absorbing heat from the radiant section of the furnace. At the lower end, the fluid enters the inner tube reversing direction and flowing upward to leave the tube at its upper end, point C. During its upward passage through the inner tube, a substantial quantity of heat is transferred to the gas flowing downward in the annulus between the inner and outer tube. The heat thus exchanged reduces by this amount the quantity of heat to be transferred from the radiant chamber to the main or outer tube, and reduces proportionately the furnace load and fuel burned.

Many heaters of this type are being used with the hot spot in the catalyst in the range of 1,300 to 1,550° F. and with

A SPECIAL FEATURE • A • I • C • E • P

Table 1.—Tube Arrangement Chemico Heaters

1.	Heater number	1	2	3	4
2.	Tube, O.D., in.	9.125	9.625	8.625	9.125
3.	Tube, heated length, ft.	24.42	24.42	23.42	23.60
4.	Tube, centers, in.	16.5	16.5	16.0	16.5
5.	A_c-external heated tube surface, sq.ft.	1170	1235	1060	1130
6.	Exposed refractory, wall surface, sq.ft.	1589	1589	1550	1530

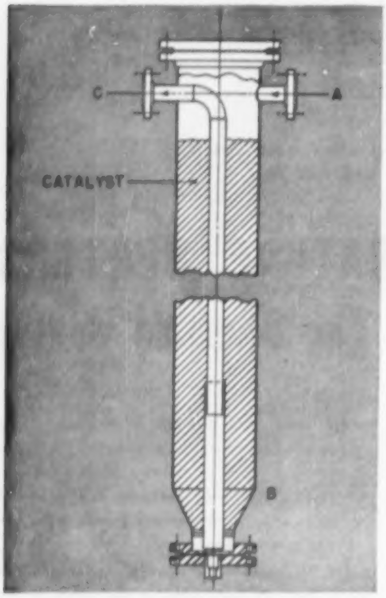

Fig. 2. Heater tube.

tube skin temperatures as high as 1,800° F.

Under such heating conditions, the tube-and-furnace arrangement (illustrated) serves to permit maximum heat transfer for any given tube skin temperature and permits lower tube-and-metal temperature than can be obtained in conventional heaters operating under the same service condition.

Apart from the thermal advantage, the use of this inner tube has certain mechanical advantages of importance. The unusually high metal temperature in this type of operation leads to a linear expansion of approximately 5 or 6 in. in the length of the tube.

With the use of the inner tube and thus with the inlet and outlet brought to the upper end of the large outer tube, it is possible to support it at the upper end and permit its free expansion downward. The lower end is simply guided and permitted to elongate freely in an insulated housing. This eliminates any mechanical strain imposed by reaction at the lower end.

The tubes are arranged for the parallel flow of fluid through all tubes. Each bank of tubes is connected to an inlet manifold and an outlet manifold at the upper end. The design problems in connection with handling of the hot fluid leaving the heater are considerably simplified by the fact that its temperature has been reduced as much as 300 or 400° F. in passing upward through the inner tube. With a fluid temperature as high as 1,500° F. in the catalyst, the fluid temperature leaving the heater may be below 1,100° F. This reduction in fluid temperature is clearly indicated in lines 4 and 5 of Table 2.

Heat Transfer in the Chemico Heater

The problem of heat transfer in the radiant furnaces of boilers and tubular-type petroleum heaters has been studied by a number of investigators and several equations and methods have been developed as a means of predicting heat absorption in this type of equipment. Reviews of these methods have been given in papers by Wilson, Lobo & Hottel (*8*), Lobo & Evans (*4*), and Wohlenberg & Mulliken (*9*).

None of the equations or methods developed to date, however, appears applicable to the Chemico heater and its performance cannot be satisfactorily predicted by their use. This is not surprising in view of the radical difference in the arrangement of the heating surface in the Chemico heater compared to conventional heaters; also, the operating

Table 2.—Test Data Chemico Heaters

1	Heater number	1	1	1	1	2	3	4
2	Test number	4	20	22	1	1	1	1
3	Fluid temp. inlet catalyst	647	620	608	621	735	650	500
4	Fluid temp. outlet catalyst	1215	1150	1201	1350	1400	1200	1492
5	Fluid temp. leaving heater	1080	1020	1030	1080	1195	932	1050
6	H-total net heat input (B.t.u.)/(hr.)(10^{-6})	29.50	24.50	20.31	17.26	35.45	20.62	24.10
7	Heat distribution							
8	Absorbed by tube surface Ac	16.60	13.27	11.20	8.14	19.75	11.70	13.74
9	In flue gas leaving heater	12.40	10.70	8.85	8.85	15.20	8.10	9.65
10	Radiation & unaccounted	.50	.53	.26	.27	.50	.82	.71
11	Per cent excess air	34.0	55.0	56.5	100.	15.0	30.0	22.0
12	Flue gas temperature, ° F.	1485	1383	1369	1329	1690	1410	1525
13	W-flue gas (lb.)/(hr.)(10^{-3})	30.5	28.75	24.1	26.15	32.0	21.1	23.0
14	R_a heat transfer rate B.t.u./(sq.ft.)/(hr.)	14,200	11,350	9,600	6,950	16,000	11,000	12,100
15	$\frac{(H)(10^{-3})}{Ac}$	25.2	21.0	17.4	14.8	28.7	19.5	21.4
16	$\frac{(H)(10^{-4})}{W}$	.097	.0848	.084	.066	.111	.098	.105
17	Equivalent heat trans. rate (a)	15,300	12,200	10.500	8,050	17,800	12,900	14,200
18	Avg. tube skin temp., ° F. (b)	1325	1225	1225	1300	1525	1275	1425
19	Fraction of heat H absorbed; item 8 divided by item 6	.565	.540	.550	.470	.560	.565	.570

(a) This "equivalent heat transfer rate" is the rate which would have been required for the same heating operation if there had been no heat transferred from the inner tube.

(b) Taken with optical pyrometer and considered accurate to approximately 25 to 50° F.

temperatures of the heat absorbing medium and the tube skin temperatures in steam-methane reforming operations are much higher than in boilers or petroleum heaters. Reference to Table 2 will show, for example, that average tube skin temperatures in the reforming heaters discussed herein are in the range of 1,225 to 1,525° F., which is approximately 400 to 500° higher than in the petroleum heaters studied by Lobo and coworkers wherein most of the tube skin temperatures are below 900° F. and only a few in the range of 900 to 1,000° F. There is an even greater difference in tube skin temperatures when compared to steam boilers. In boilers the tube wall temperature is usually within 50° F. of the saturation temperature of the steam.

A complete study of the heat transfer effects in packed tube heaters of this type would require a careful investigation of the heat transfer phenomenon within packed tubes at high temperatures, wherein conduction, radiation, and convection each play a part. This study would be necessary for the purpose of predicting the tube skin temperatures, which in turn have an effect on over-all heat transfer. The problem of heat transfer within the packed tube is complicated further by the fact that the packing material in this instance is a catalyst and that the major portion of the heat transferred into and through the packing is utilized in the reaction and does not appear as sensible heat in the material being heated. Although there is some published data on heat transfer in packed beds, it is, in general, directed to comparatively low temperature operations and does not appear applicable to the present case.

Although in this presentation, no attempt has been made to study the problem of heat transfer within the packed tube because of its complexity, its importance, however, should not be overlooked. Reference to Table 2 shows that the temperature drop through the packing is considerable and it must receive due consideration in design if excessive tube temperatures are to be avoided.

Specifically in the present study of seven tests on four different heaters, a method of predicting over-all heat transfer and heat absorption efficiency has been developed, which is based on the firing condition or heat generating conditions only. Other factors which influence heat transfer have not been included in the present correlation as they are in effect constant (or vary only within narrow limits) for the type of heater and operating conditions under study.

As seen from Table 1 the furnaces are similar in physical design and use the same tube arrangement; also the ratio of the tube spacing to tube diameter is virtually constant. The same holds true also for ratios of refractory surface or furnace volumes to tube surface. The skin temperatures of the tubes also, although relatively high, are nevertheless all within a limited range of temperature. These factors are, therefore, in a sense, constant for the present study and performance, as mentioned previously, has been related only to the important variables in the firing conditions.

The performance data on the heaters considered unusually precise are given in Table 2.

In each case, a mixture of natural gas and steam or of natural gas, steam, and carbon dioxide enters all furnace tubes at the upper ends and flows downward through the catalyst-filled tubes; all tubes operate in parallel. The reaction products leave the catalyst bed at the lower end of the tubes and flow upward through the inner tubes leaving at the upper end, where each bank of tubes is connected to a manifold.

Before entering the heater tubes the reactants are separately measured on recording flow meters. A check on this measurement is obtained by a separate steam : gas ratio metre in which a measured amount of steam (measured as condensate) is collected, while the gas from which it has been condensed is accurately measured in a wet test meter. The product gas leaving the furnace is, of course, analyzed and a steam : gas ratio is taken at the furnace exit. After passing through other process equipment, the product gas is measured by a flow recorder and analyses are made also at this point. Thus by means of the product gas meters, and steam : gas ratio meters,

Fig. 1. Chemico reforming heater.

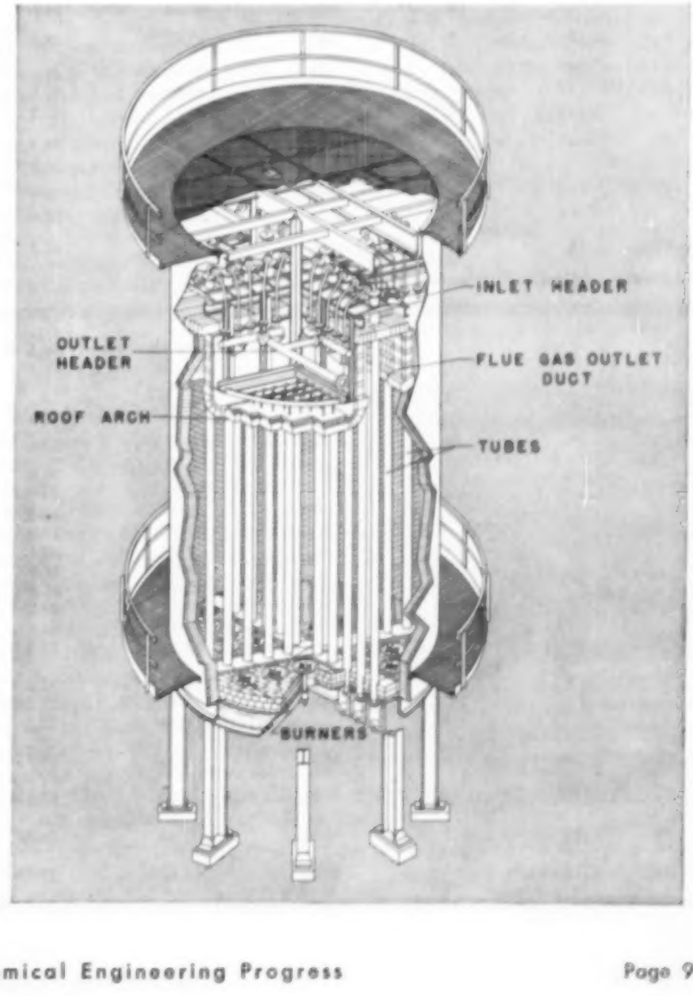

Table 3.—Refinery Heaters—Type B & E

Line no.	Heater type	Heater no.	Test no.	Tube surface $\alpha\ A_{cp}$	Heat input H (B.t.u.)(10^{-6})	$\frac{(H)(10^{-3})}{\alpha\ A_{cp}}$	$\frac{(H)(10^{-6})}{W}$	Heat absorbed q (B.t.u.)(10^{-6})	Rate of heat transfer R_e (B.t.u.)(10^{-3})
1	B	2	1	756	24.58	32.5	.0638	10.73	14.20
2			2		20.94	27.7	.0488	6.30	8.33
3			3		19.55	25.8	.0542	7.24	9.56
4			4		23.55	31.1	.0860	11.58	15.30
5			5		22.16	29.3	.0870	11.24	14.85
6			6		25.46	33.6	.0805	11.80	15.60
7			7		26.71	35.3	.0716	11.39	15.10
8			8		27.78	36.7	.0722	11.36	15.0
9			9		19.28	25.5	.0505	7.18	9.49
10			10		20.23	26.7	.0515	7.64	10.10
11			11		14.58	19.2	.0695	7.37	9.73
12			12		14.30	18.9	.0756	7.75	10.25
13			13		16.13	21.3	.0622	7.55	9.97
14			14		17.84	23.6	.0602	7.96	10.50
15			15		23.40	30.9	.0614	9.73	12.85
16			16		18.54	24.5	.0807	10.14	13.40
17			17		20.64	27.3	.0734	10.09	13.35
18	B	4	1	1343	38.33	28.5	.0875	18.78	13.97
19			2		41.84	31.1	.0780	19.13	14.24
20			3		39.09	29.1	.0748	17.17	12.77
21			4		34.65	25.8	.0741	15.25	11.35
22			5		54.94	40.85	.0721	23.68	17.60
23			6		44.59	33.20	.0712	17.58	13.08
24			7		46.11	34.30	.0703	18.09	13.45
25	B	9	1	1844	81.56	44.30	.110	44.60	24.2
26			2		83.01	45.0	.102	44.63	24.2
27			3		79.07	42.85	.1125	42.71	23.15
28			4		85.90	46.50	.0936	41.48	22.50
29	B	12	1	1197	48.48	40.5	.0832	24.88	20.8
30			2		41.66	34.9	.0733	20.03	16.75
31	B	17	1	887	42.19	47.6	.0778	16.89	19.0
32	B	18	1	965	39.99	41.4	.0782	17.41	18.05
33			2		40.60	42.1	.0778	17.46	18.08
34			3		39.79	41.2	.0670	15.52	16.08
35	E	6	1	1608	88.56	55.2	.113	45.66	28.4
36			2		90.04	56.0	.1127	45.46	28.2
37	*E	7a	1	3610	184.7	51.1	.1008	104.6	29.0
38		7b	1	3698	138.6	37.4	.0880	74.1	20.04
39	E	19	1	1820	87.5	48.1	.0635	32.97	18.10

* This heater has two radiant sections.

Table 4.—Refinery Heaters—Type C & D

Line no.	Heater type	Heater no.	Test no.	Tube surface $\alpha\ A_{cp}$	Heat input H (B.t.u.)(10^{-6})	$\frac{(H)(10^{-3})}{\alpha\ A_{cp}}$	$\frac{(H)(10^{-6})}{W}$	Heat absorbed q (B.t.u.)(10^{-6})	Rate of heat transfer R_e (B.t.u.)(10^{-3})
1	C	3	1	2255	46.93	20.8	.085	24.66	10.9
2			2		56.41	25.0	.0667	23.61	10.45
3			3		50.32	22.3	.0948	26.61	11.8
4			4		51.86	23.0	.0925	27.03	11.20
5			5		56.90	25.2	.0734	26.17	11.58
6			6		64.96	28.8	.089	34.93	15.47
7			7		62.22	27.6	.082	31.04	13.75
8			8		60.56	26.8	.0797	29.36	13.00
9			11		49.03	21.7	.0633	19.92	8.85
10			12		52.50	23.3	.0715	23.56	10.43
11	D	5	1	2303	50.57	22.0	.0662	21.11	9.16
12			2		54.41	23.6	.0637	22.40	9.72
13			3		57.96	25.2	.0714	26.27	11.40
14	D	13	1	2108	56.36	26.75	.1247	34.53	16.4
15	D	14	1	2108	46.10	21.87	.113	26.09	12.4
16	D	15	1	1928	52.46	26.25	.125	31.01	16.1
17	D	16	1	2108	58.46	27.75	.1135	34.45	16.35

there are at least two cross checks on the accuracy of inlet flow meters.

The heat absorbed by the tubes was calculated in all cases from the measured flow of the reactants to the heater and the analysis of the natural gas to the heater and the reformed gas leaving the heater. The heat capacities, heats of formation, and heats of combustion of all the gases in the process are well established.

The total net heat liberation by fuel and air is denoted by H. This includes the sensible heat (above 60° F.) of the combustion air entering the heater plus the heat of combustion of the fuel. The fuel gas was measured on recording flow meters and analysis and heating values were available in all cases. Excess air and combustion air were determined by flue gas analysis and carbon balance against fuel; recording CO_2 meters were used in some tests and Orsat analysis in others.

Preheated air was used in all tests and the sensible heat in the combustion air was determined by thermal balance over the air preheater. The heat given up by the flue gas is taken as the sensible heat in the combustion air. This corrects for that portion of air which is not preheated and enters as leakage in the furnace casings or is aspirated directly by the burner without benefit of preheat.

The temperature of flue gas leaving the furnace was measured by thermocouples located in the exit flue. The location is such that no tubes or cold surfaces are within radiating range of the couples.

The residual heat in flue gas leaving the heaters is determined by this temperature and the quantity of flue gas as calculated from fuel measurement, flue gas analysis, and carbon balance.

The heat lost by radiation from the furnace shell to the surroundings is taken as the difference between the total heat input H and the sum of the heat absorbed by the tubes plus the heat content of the flue gas. This is really a radiation plus unaccounted loss and varies for the tests herein from approximately 1.3 to 4.0% of the input H; most values are below 2.0%.

Performance data on the several heaters and the factors with which heat transfer rates are correlated are given in Table 2. The data are plotted in Figure 3.

In Figure 3, heat transfer rate R_a B.t.u./(hr.)(sq.ft.) is plotted as a function of two factors:

$$\left(\frac{H \times 10^{-3}}{Ac}\right)^{.96} \text{ and } \left(\frac{H \times 10^{-4}}{W}\right)^{.333}$$

The equation of the line plotted in Figure 3 is

$$R_a = 1370\left(\frac{H \times 10^{-3}}{Ac}\right)^{.96} \times \left(\frac{H \times 10^{-4}}{W}\right)^{.333} \quad (1)$$

The first factor $(H)(10^{-3})/Ac$ is a simple relationship between the heat liberated in the combustion chamber and the amount of heat absorbing surface exposed to direct radiation from the flame and combustion products. It may be thought of as the firing rate of the heater.

The second factor $(H)(10^{-4})/W$ is not a quantitative or rate factor but is a measure of the heat intensity of the combustion process and an indirect measure of the theoretical flame temperature. It is determined fully from the type and heating value of the fuel, the excess air, and the air preheat; it is not necessary to know the actual values of H and W.

For example, having the type of fuel, excess air, and air preheat, one can by simple calculation determine the pounds of combustion products (wet basis) produced for each 10,000 B.t.u. in fuel plus air.

And if this is given the value X, then

$$\frac{1}{X} = \frac{(H)(10^{-4})}{W}$$

In heater calculations and design, the practice is to calculate the value of X based on the type and heating value of the fuel to be used and the expected combustion conditions as to excess air and air preheat, if any.

The average deviation of the test data from the values calculated by the above equations is 2% and the maximum deviation is 5%.

Subsequent studies on other types of furnaces confirmed the fact that the general equation

$$R = C(A)^x(B)^y \quad (2)$$

can be used for correlating the performance data of a wide variety of radiant furnaces differing greatly in design. The value of the constant C and the exponents x and y appear to be determined primarily by the geometrical arrangement of the furnace enclosure, arrangement of heating surface and burners. Secondary factors are probably furnace volume, type of fuel, area of refractory surface, and possibly others.

The terms A and B, of course, are the heat input H per unit of surface area, and per unit weight of combustion products as used in Equation (1). The exponents of these terms are separately determined from the test data by means of a logarithmic plot of selected runs or tests—the exponent of the A term requiring a plot of A vs. heat transfer rate for a number of test points or runs in which the B term has a substantially constant value; the exponent of the B term similarly is determined from a set of test points having a constant value for A.

Heat Transfer in Refinery-Type Heaters

In view of the satisfactory results obtained by the use of Equation (1) for correlating heat transfer data on the high temperature reforming heaters, it was considered of interest to determine what the application of a similar method to other types of heaters or furnaces would yield.

A preliminary study was made of the performance data on the refinery-type heaters reported by Wilson, Lobo, and Hottel (8), and also the heaters covered by Lobo and Evans (4). The first paper used some sixty-two tests on twelve different heaters, and the second paper eighty-five tests on nineteen heaters.

The tests on five of the heaters reported in the first paper were used again in the paper by Lobo and Evans (4) and many differences are noted in the performance data for these heaters as reported in the two papers. The data as reported by Lobo and Evans (4) were used therefore in further studies on the assumption that the changes noted in the later paper reflected corrections to the earlier data.

The test data in the Lobo and Evans (4) study, covers work on seven types of heaters which differ widely in physical design. The different types are identified by the letter symbols A to G. The preliminary study

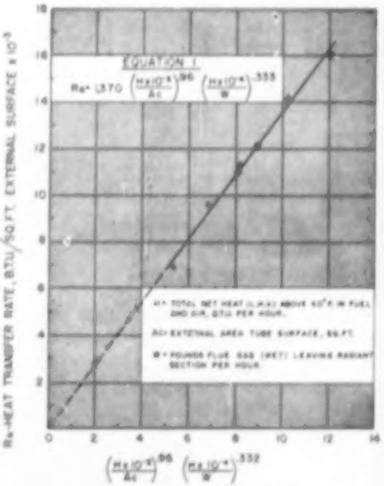

Fig. 3. Heat transfer, Chemico heaters, Equation (1).

Table A.

			Empirical Equation (8)	Theoretical Equation (4)
Type-B heater (avg. of 34 tests)	Eq. (3)	1.025	.95	.97
Type-E heater (avg. of 5 tests)	Eq. (3)	1.05	1.05	1.06
Type-C heater (avg. of 10 tests)	Eq. (4)	.997	.95	.99
Type-D heater (avg. of 7 tests)	Eq. (5)	1.004	.96	.97

of the data appeared to indicate that possibly the most useful result would be obtained by studying separately the different types of heaters in an effort to establish whether or not the physical difference in design could be related to difference in heat transfer performance.

The heaters included in the present study are types B, C, D, and E as illustrated in Figures 4A, 5A, and 6A. The type E heater is not illustrated as it is similar to type B except that it has a double radiant section with common convection tubes.

HEAT TRANSFER TYPE-B AND -E HEATERS

The data for this study are given in Table 3.

In an analysis of the data on the refinery heaters the practice of the authors of the original papers on the heaters (*2, 3*) has been followed and for external tube surface the equivalent cold plane $\alpha\ Acp$ as developed by Hottel (*3*) has been substituted. This gives a different value for the constant C in the general equation from that if actual external surface were used. It does not however affect the values of the exponents.

In Figure 4

$$\left(\frac{H \times 10^{-3}}{\alpha Acp}\right)^{.70} \left(\frac{H \times 10^{-4}}{W}\right)^{.85}$$

is plotted against heat transfer rate Re in B.t.u./sq.ft. $\alpha\ Acp$. The equation determined from this plot and applying to the type B and E heaters shown in Figure 4A is:

$$Re = 11{,}400\left(\frac{H \times 10^{-3}}{\alpha Acp}\right)^{.70} \left(\frac{H \times 10^{-4}}{W}\right)^{.85} \quad (3)$$

HEAT TRANSFER TYPE-C HEATERS

Figure 5 is a plot with data from Table 4. The equation for heat transfer in the C-type heater (Figure 5A) as determined from this plot is:

$$Re = 1{,}450\left(\frac{H \times 10^{-3}}{\alpha Acp}\right)^{1.13} \left(\frac{H \times 10^{-4}}{W}\right)^{.60} \quad (4)$$

HEAT TRANSFER TYPE-D HEATERS

This vertical tube, cylindrical shell heater is in wide use today with various modifications in details of design. These seven tests on five different heaters provide sufficient data to establish an equation which correlates the performance data of the heaters.

Figure 6 is a plot of the data on the D-type heater (shown in Figure 6A) and the equation for its performance is:

$$Re = 1{,}400\left(\frac{H \times 10^{-3}}{\alpha Acp}\right)^{1.13} \left(\frac{H \times 10^{-4}}{W}\right)^{.60} \quad (5)$$

Wilson, Lobo, and Hottel (*8*) developed a modification of the Orrok (*6*) equation to correlate the data on their heaters. Lobo and Evans (*4*) suggested a theoretical equation based on the fourth power law including the use of an over-all exchange factor to correct for flame emissivity, arrangement of refractory, and volume and shape of combustion chamber. They compared the calculated values of heat absorbed as determined by both equations with the actual values as found in the tests. Table A is a summary of a similar comparison including the values determined by Equations (3), (4), and (5).

The above comparison confirms the fact that the proposed equations give a slight though not significantly better correlation than the Lobo and Evans theoretical equation. The simplicity of the equations and the fact that they provide a direct graphical comparison between different designs would appear to be an advantage in their use.

Comparative Performance Refining Heaters and Reforming Heaters

After a development of the different performance equations of the several heaters previously discussed, it is possible to compare their performance when operated under identical firing conditions—at the same rate of heat input H and with the same excess air for all heaters.

In Figure 7, the type-B and -E heaters are compared with the type-D heater over a wide range of heat input H and with excess air constant at 30%. This comparison shows clearly that the type-B and -E heaters give a greater heat input per square foot of equivalent cold plane surface.

In Figure 8, the comparison includes the Chemico heater and is based on heat transfer per square foot of external surface. In spite of the considerably higher tube wall temperature the heat transfer is markedly greater in the Chemico heater because of the fact that both sides of all tubes are exposed to direct radiation. Stated another way, the effective cold plane for the Chemico heater per unit of tube surface is considerably greater than for the refinery heaters with which it is compared.

Heat Transfer in Steam Boilers and Superheaters

In recent years, some extremely interesting work has been done in the testing of large central station boilers. Most of the work has been published and subject to considerable study.

The above methods of correlating heat transfer data have been applied to several of these boilers and to a steam superheater. The projected area of the water wall surface is used as Ap. The values of C, x, and y in Equation (*2*) are given in Table 5 along with reference to the original test work. Details of these correlations are on file with A.D.I.

The correlation of heat transfer by the use of Equation (2) with the constants indicated for all of the boilers and superheaters listed in Table 5 gives a more satisfactory correlation of data than methods previously used. It also permits comparing performance of the heaters or boilers on a more equitable basis.

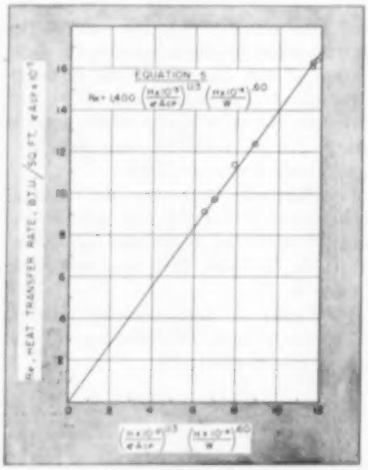

Fig. 6. Heat transfer, type-D heaters, Equation (5).

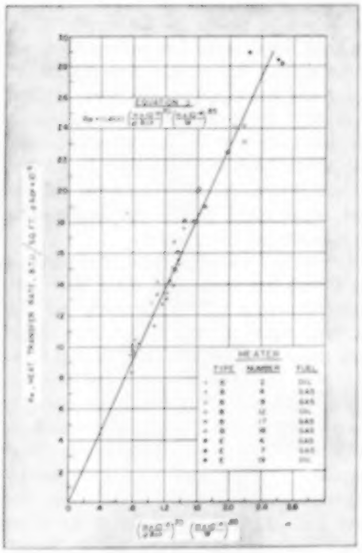

Fig. 4. Heat transfer, type-B & -E heaters, Equation (3).

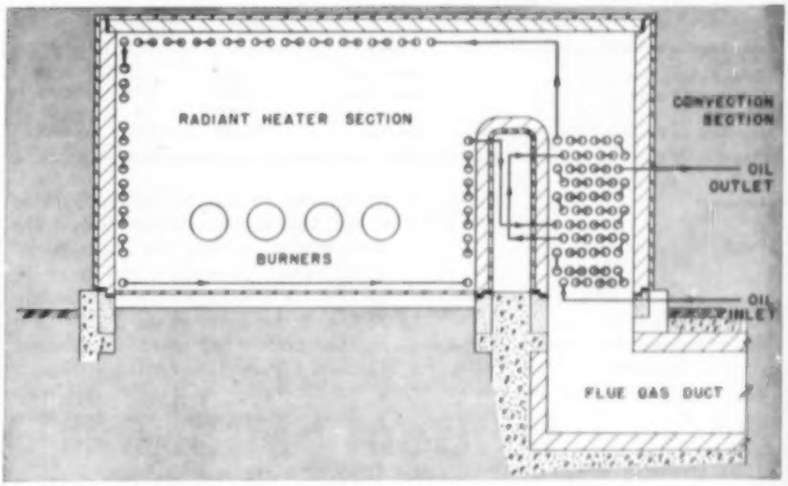

Fig. 4A. Type B.

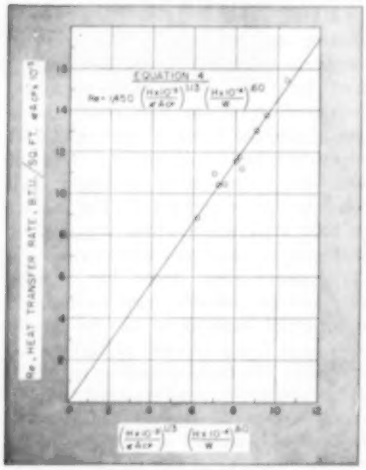

Fig. 5. Heat transfer, type-C heaters, Equation (4).

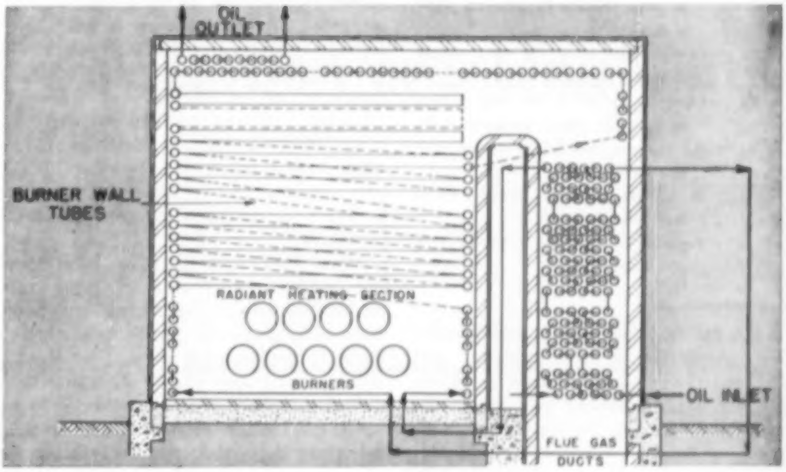

Fig. 5A. Type C.

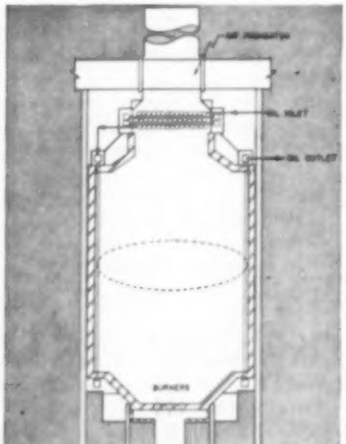

Fig. 6A. Type D.

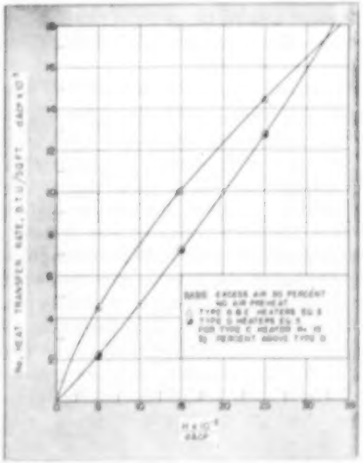

Fig. 7. Comparison refinery heaters, identical firing conditions.

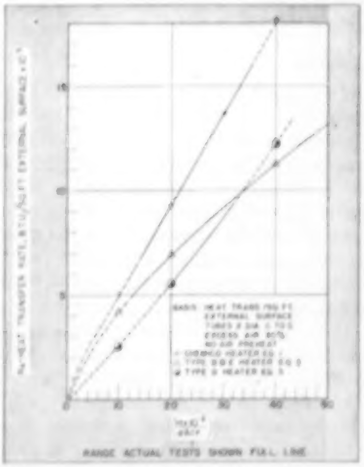

Fig. 8. Comparison—Chemico reforming vs. refinery heaters.

Table 5.—Equations for Steam Boilers and Superheaters

Literature Cited	Fuel	Equation (2) C	x	y
Reid, Cohen, Corey (7)	pulv. coal	7,200	.75	.70
Corey and Cohen (2)	pulv. coal	8,625	0.70	0.70
Blizzard (1)	oil	8,500	0.8	1.0
Mumford and Corey (5)	nat. gas	13,250	0.7	0.87

Notation

$A = \frac{H}{Ac}, \frac{H}{Acp}$ or $\frac{H}{Ap}$

Ac = external area of heat absorbing surface, sq.ft.

Ap = projected area of heat absorbing surface, sq.ft.

αAcp = equivalent effective tube surface

$B = \frac{H}{W}$

C = constant in general equation

H = total net heat input (L.H.V.) above 60° F. in fuel and air, B.t.u./hr.

R_c = heat transferred to the tube surface as B.t.u./(hr.)(sq.ft. external tube surface)

Re = heat transferred to the tube surface as B.t.u./(hr.)(sq.ft. α Acp).

Rp = heat transferred to the tube surface as B.t.u./(hr.)(sq.ft. projected area)

W = lb. flue gas (wet basis) leaving radiant section/hr.

X = lb. flue gas, wet basis/10,000 B.t.u. in fuel plus air (L.H.V.)

x = exponent of terms A

y = exponent of terms B

Acknowledgment

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Appendix

The present study differs from that of most earlier investigations in several particulars: first the direct use of heat transfer rate in correlating the data and as a measure of performance. Most prior studies use instead the fraction or per cent of heat input which is absorbed by the cold surface. In steam boiler work, the traditional method is the use of furnace efficiency.

It is the author's belief, after numerous attempts at correlation by other methods, that heat transfer rate is susceptible to better correlation with the design or operating variables than is furnace efficiency. Clearly, it is more sensitive to changes in these variables. For example, in the series of tests on the Chemico heater, as shown in Table 2, the heat transfer varies from 6,950 to 16,000 B.t.u./sq.ft., or a change of 230%, while efficiency varies from 47 to 57%, or a change of approximately 22% over the lower value. In the case of the direct fired steam superheater furnace, Figure 12A (A.D.I.) there is a tenfold change in transfer rate with a change in absorption efficiency from 23.3 to 39% or less than a twofold variation.

Again with reference to Table 2 (lines 14 and 19) of the Chemico heater, it will be seen that there is no consistent relationship between heat transfer rate and the fraction of heat absorbed. In particular, for high temperature heaters, it appears that a direct determination of efficiency or fraction absorbed requires correlation with a more complex set of variables than when heat transfer rate is used. This may be true to a lesser extent on boilers or furnaces with low tube temperatures.

Most investigators have been influenced by the early work of Orrok and various forms of the Orrok equation have been proposed. Probably its most accurate modification is used by Read, Cohen, and Corey (7) in analyzing the data on furnace shown in Figure 9A (A.D.I.). When plotted for the clean tube test conditions on this heater, it gives a quite reasonable correlation with an average deviation of the test data from the line of the equation of 1.94% and a maximum deviation of 3.64%. Equation (6) of the present paper gives an average deviation of 1.37% and a maximum of 2.90%.

If applied over a wide range of heat input, however, as in the case of the steam superheater furnace, Figure 12A, (A.D.I.) it will be seen that as pointed out by others (7), it falls far short of presenting a good correlation except over a limited range. In this instance, the test points for the higher range or for the lower range of heat transfer can be spotted fairly close to a line representing the equation, but depending on which is given weight in the plot, the other suffers seriously. It is not possible to draw a satisfactory line for this equation with all the test data being used.

The original Orrok equation states that furnace efficiency varies inversely as the square root of the heat input. The use of the ½ power as the exponent of the heat input term has persisted in all modifications of which the author is aware and the equation has been applied to widely different heater designs. It has been shown in the present study that when heat transfer rate is related to heat input H, the exponent of the heat input term differs markedly with various designs of heater.

Similarly, various modifications of the Orrok-type equation state that furnace efficiency varies inversely as the air/fuel ratio (8) or the flue gas/heat ratio (7) taken to the first power. This flue gas per heat ratio is the reciprocal of the term H/W as used in the present study. Again, it seems clear from the present investigation that heat transfer (as distinct from efficiency) although varying with H/W does not have as simple a relationship to it as many assume. As shown in the present study, the exponent of the H/W term differs markedly for different designs.

One of the basic shortcomings of the Orrok-type equation is the fact that it indicates as theoretically possible the absorption of 100% of the heat introduced into the combustion chamber, whereas in truth the theoretical maximum absorption is set by the tube wall temperature and could only be achieved when the combustion products are cooled to this temperature. The higher the tube wall temperature the greater the degree of error this introduces.

It appears clear from the present study and particularly from analysis of the original references on the steam boiler tests that a number of factors not covered by the usual equations or methods of predicting heat transfer have at least a secondary effect on performance. These include burner position, length of gas path, location of flue outlets and gas impingement on the heated surface.

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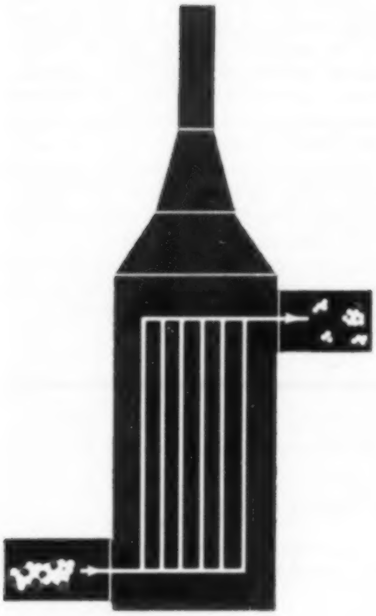
Presented at A.I.Ch.E. meeting, Houston, Texas.

New Methods of HEATER DESIGN



This new method is said by the authors to require only one-fourth the time usually required with the stepwise trial-and-error method in general use.

A simplified method for designing light hydrocarbon cracking units

Thomas K. Perkins and Howard F. Rase

The University of Texas

A new design method is certainly worthy of consideration if it can save many hours of calculating time, and yet produce results consistent with the accuracy of the data. This paper describes a method for designing light hydrocarbon thermal cracking units which requires approximately one quarter of the time needed to determine the same results by the stepwise trial-and-error procedure now in general use.

The usual stepwise integration (*1*) involves trial and error. The temperature and pressure at the end of an increment must be assumed before the average properties of the gases and reaction rate can be determined for that increment. The less tedious calculation procedure described in this paper accomplishes the same stepwise integration without requiring trial and error. It should, therefore, be of particular value when several preliminary studies are necessary to establish the optimum design.

Other simplified design methods have been proposed (*3*), but it is believed that the method described in this paper will be more flexible.

Design Equations

An examination of a number of design calculations and plots of pressure, temperature, and conversion vs. tube number has shown that design equations may be integrated by the use of certain average conditions, or that numerical integration methods may be employed. Derivations of the equations outlined below are presented later in this paper.

PREHEAT SECTION

As pointed out by Murdoch and Holland (*3*), the preheat-section of the furnace may be treated in one step. Using such a one-step approach, one obtains the following equations:

(a) Temperature at the end of the preheat section (t_E) is that temperature corresponding to

$$k_E = \frac{(0.001)F(1+n_i)}{(V_T)(P_E)} \qquad (1)$$

This is based on the definition that the end of the preheat section is that point at which

$$\frac{da}{dV} = \frac{0.001}{V_T}$$

Each term on the right side of Equation (1) is known except P_E. This pressure at the end of the preheat section is assumed, the temperature corresponding to k_E is determined, and the assumed pressure then is checked with the following equation.

(b) Pressure at the end of the preheat section (see Equation (2) below).

This is the *only* trial-and-error solution of equations that is required by this method. When these two equations are properly solved, the number of tubes in the preheat section can be determined immediately by

$$N_E = \frac{F(C_p)_{avg.}}{\phi}(t_E - t_o) \qquad (3)$$

$$P_E = \sqrt{P_o^2 - \frac{[(P_F)'_E + (P_F)_o]F(C_p)_{avg.}L'(t_E - t_o)}{\phi}} \qquad (2)$$

A • C • E • P SPECIAL FEATURE

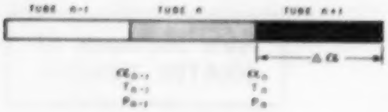


Fig. 1. Explanation of notation.

REACTION SECTION

In the reaction section, design equations may be solved by numerical integration methods. The resulting equations are as follows:

(a) Conversion occurring in any tube:

$$\Delta a = \frac{3}{2}\left[\frac{kPV_T(1-a)}{F(1+n_f+\delta a)}\right]_n - \frac{1}{2}\left[\frac{kPV_T(1-a)}{F(1+n_f+\delta a)}\right]_{n-1} \qquad (4)$$

Subscript n denotes the inlet conditions of the tube under consideration, and subscript $n-1$ denotes the inlet conditions of the preceding tube. (See Figure 1).

(b) Temperature rise resulting in any tube:

$$\Delta t = \left(\frac{\phi}{FC_p}\right) - \left(\frac{H_R}{C_p}\right)\Delta a \qquad (5)$$

(c) Outlet pressure of any tube,

$$P_2 = \sqrt{P_1^2 - 2(P_p)L'} \qquad (6)$$

Hence, the temperature, pressure, and total conversion at the end of each tube in the reaction section can be determined without trial-and-error calculations. Calculations for the entire reaction section can be tabulated on one or two sheets of paper.

This method can be used for cases in which changes in heat flux, heat capacity, and heat of cracking occur rapidly with changes in temperature or conversion. It is not limited to low conversion, but may be applied over any range for which suitable data are available.

Calculation Procedure

Equations (4), (5), and (6) can be used in a systematic tabular-type calculation procedure that is simple and rapid. The procedure is outlined below and is followed by an example problem.

I. WORKING CHARTS

As indicated by Fair and Rase (*1*), it is convenient to prepare the following working charts (Figures 2-7).

(1) A product distribution chart should be established and used in preparing the other charts concerning physical properties of the system. Schutt's data (*4*) may be used for light hydrocarbons.

(2) k(lb. moles/(hr.) (cu.ft.) (lb./sq.in. abs.) vs. t °F. velocity constant data for light hydrocarbons have been summarized (*1*).

(3) Heat capacity (based on fresh charge) (B.t.u./° F./lb.-mole fed) vs. t °F., with conversion as a parameter.

(4) P_P vs. t° F., with conversion as a parameter. Viscosity of the mixture may be obtained by the method of Uyehara and Watson (*5*). A new chart must be prepared for each flow rate and tube diameter. This, however, presents little difficulty when the relation of viscosity vs. temperature and conversion has been established.

(5) Differential heat of cracking (B.t.u./lb. mole reacting) vs. conversion with temperature as a parameter. For any degree of conversion on the product distribution curve, determine the number of moles of each gas per mole of reactant fed. Multiply the number of moles of each gas by its heat of formation at the temperature under consideration, and plot the sum of these heats of formation vs. degree of conversion. The differential heat of cracking chart can be obtained by graphically differentiating this curve.

(6) In addition to these five charts, it is convenient to prepare a chart of

$$\left(\frac{1-a}{1+n_f+\delta a}\right) \text{ vs. } a$$

Expansion factors for light hydrocarbons have also been summarized (*1*).

II. PREHEAT SECTION

(1) Assume the pressure at the end of the preheat section.

(2) Solve for k_B from Equation (1).

(3) Determine t_B corresponding to k_B.

(4) Find t_A

$$t_A = \frac{t_B + t_o}{2}$$

(5) Determine $(C_p)_{avg.}$ at 0% conversion by the following formula.

$$(C_p)_{avg.} = \frac{[(C_p)_O + 4(C_p)_A + (C_p)_B]}{6}$$

(6) Calculate P_B using Equation (2).

(7) Check the assumed value of P_B and repeat steps 1-6 if necessary.

(8) Calculate the number of tubes in the preheat section using Equation (3).

Table 1.—Tabulation of Reactor Section Calculations

1	2	3	4	5	6	7	8	9	10	11	12	13
N_R	an	Δa $\left(a_n - \frac{\Delta a}{2}\right)$	C_p	H_R	$\frac{\phi}{FC_p}$ *	$\frac{H_R \Delta a}{C_p}$	T_n	k	$2L'(P_p)$ P^2	P	$\left(\frac{1-a}{1+\delta a}\right)_n$	Y_n $1.5Y_n$ $0.5Y_{n-1}$ Δa
0	0						1109		3240			0.001 = Δa
1	0.001	0.001							100			0.00264 = y_n
		0.005	39.2	37,000	48.1	0.94	1156	3.35×10^{-5}	3140	56.0	1.0	0.00396 = 1.5 y_n 0.0005 = $0.5y_{n-1}$ 0.00346 = Δa
2	0.00446	0.00346										
		0.00273	………	………	………	………	etc.	………	………	………	………	

* $\frac{\phi}{F}$ = 1888

Complete Table 1 is on file (Document 4806) with the A.D.I. Auxiliary Publications Project, Library of Congress, Washington, D. C., obtainable by remitting $1.25 for microfilm and $1.25 for photoprint.

III. REACTION SECTION

(1) Prepare a table similar to Table 1.

(2) In cols. 4 and 5, for any tube n, tabulate C_p and H_R evaluated at T_{n-1} and $\left(a_n - \frac{\Delta a}{2}\right)$

(3) Calculate ϕ/FC_p and $H_R\Delta a/C_p$ and enter in cols. 6 and 7.

(4) Calculate T_n and enter in col. 8.

$$T_n = T_{n-1} + \left(\frac{\phi}{FC_p}\right) - \left(\frac{H_R\Delta a}{C_p}\right)$$

T_n = (previous entry col. 8) + (entry col. 6). − (entry col. 7).

(5) Find k_n corresponding to T_n and enter in col. 9.

(6) Find the pressure drop factor corresponding to T_n and $(a_n - \Delta a/2)$.

Calculate $(2L'\ P_F)$, enter in the top line of col. 10 for tube n, subtract from $(P_{n-1})^2$ tabulated above and enter $(P_n)^2$ in the second line of col. 10.

$$P_n{}^2 = (P_{n-1})^2 - 2L'(P_F)$$

(7) Take the square root of $(P_n)^2$ and enter P_n in col. 11.

(8) On Figure 7, look up

$$\frac{(1-a)}{(1+n_I+\delta a)}$$

evaluated at a_n (not $a_n - \Delta a/2$) and enter in col. 12.

(9) Calculate y_n by multiplying (V_T/F) (col. 9) (col. 11) (col. 12)

$$y_n = \left(\frac{V_T}{F}\right)(k_n)(P_n)\left(\frac{1-a}{1+n_I+\delta a}\right)_n$$

and enter in the top line of col. 13 for tube n.

(10) Multiply y_n by 1.5 and enter in second line.

(11) Divide y_{n-1} (from tube above) by 2 and enter in third line.

(12) Subtract entry of third line from

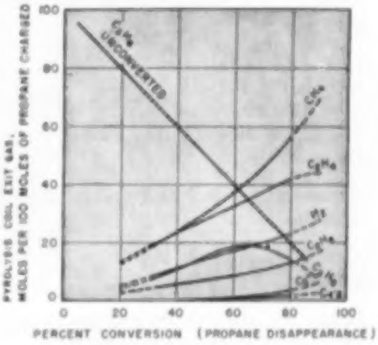


Fig. 2. Product distribution curves for propane (4).

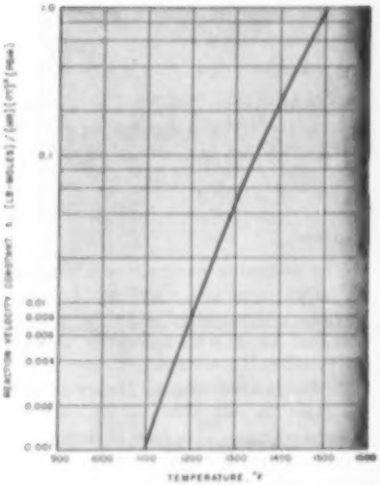


Fig. 3. Reaction velocity constant vs. temperature for propane (1).

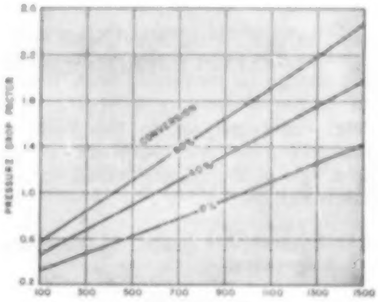


Fig. 5. Pressure drop factor for propane cracking.
Basis: 7000 lb./hr. charge, 4.0-in. I.D. tube.

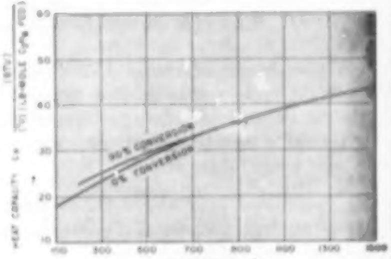
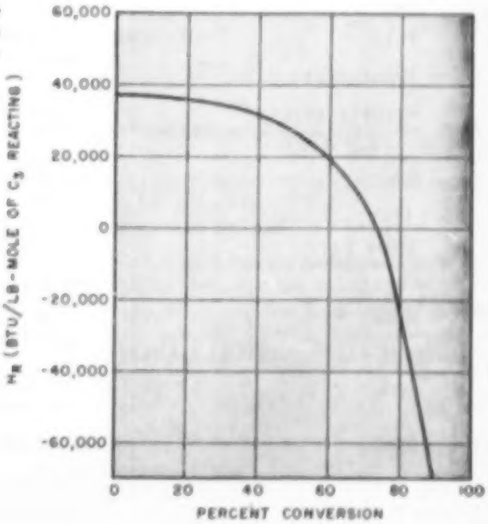


Fig. 4. Heat capacity (based on fresh charge).

Fig. 6. Differential heat of cracking propane (980-1520° F.).



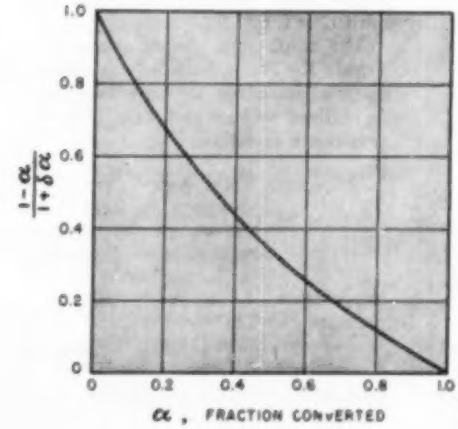


Fig. 7. Conversion and expansion relation for propane.

entry of second line to obtain Δa.

$(\Delta a) = 3/2 y_n - 1/2\ y_{n-1}$

This should also be tabulated as Δa in column 3 for the next tube $(n+1)$.

(13) Calculate y_{n+1} and $(y_{n+1} - \Delta a/2)$ and enter in cols. 2 and 3 of the next line.

$a_{n+1} = a_n + (\Delta a)$

The temperature, pressure, and conversion at the end of the nth tube in the reaction section are now tabulated.

$N_{total} = N_E + N_R$

Example

The following example will illustrate the calculation procedure more clearly. Results are compared with the solution obtained by a trial-and-error stepwise integration.

A direct-fired tubular heater is to be designed for the pyrolysis of 7,000 lb./hr. of propane. The flow is in one continuous pass through a series of horizontal tubes connected by welded return bends. The tubes are 4-in. I.P.S., Schedule 40, austenitic-type stainless steel, of 24 ft.-0 in. straight length and located on 12-in. centers. All tubes and return bends are exposed to a heat flux of 10,000 B.t.u./(hr.)(sq.ft.) outside area.

If the charge enters at 150° F. and 65 lb./sq.in.abs., it is desired to calculate the number of tubes, exit pressure, and total conversion corresponding to an exit temperature of 1,475° F.

V_T ....2.24 cu.ft.
heated surface, outside ......30.0 sq.ft.
L', equivalent pressure drop length of one tube and bend...44.0 ft.

PREHEAT SECTION

Assume P_E = 50 lb./sq.in.abs.

$$F = \frac{7{,}000}{44.1} = 159$$

Using Equation (1)

$$k_E = \frac{(0.001)(159)(1)}{(2.24)(50)} = 1.42 \times 10^{-3}$$

From Figure 2

t_E = 1,115° F.

$$t_A = \frac{150 + 1{,}115}{2} = 632° \text{ F.}$$

From Figure 4

$$(C_p)_{avg.} = \left[\frac{(19.5) + 4(31.1) + (39.3)}{6}\right]$$
$= 30.6$

From Figure 5

$(P_F)_{t0} = (0.36)$
$(P_F)_{tE} = (1.105)$

Therefore using Equation (2)

$$P_E = \sqrt{(65)^2 - \frac{[0.36 + 1.105](159)(30.6)(44)[1.115 - 150]}{300{,}000}}$$

P_E = 57.6 lb./sq.in.abs.

Assume P_E = 57.6 and repeat the calculations.

$k_E = 1.23 \times 10^{-3}$
t_E = 1,108° F.
t_A = 628° F.
$(C_p)_{avg.} = 30.3$, $(P_F)_E = 1.10$
$P_E = 56.9$

Assume P_E = 56.9 and repeat the calculations

$k_E = 1.248 \times 10^{-3}$
t_E = 1,109° F.

Hence, the other values will not change, and the last assumption is correct.

Using Equation (3)

$$N_E = \frac{(159)(30.3)}{(300{,}000)}(1{,}109 - 150)$$
$= 15.4$ tubes

REACTION SECTION (NUMBERS REFER TO THOSE IN "CALCULATION PROCEDURE.")

The end of the preheat section is defined as that point in the reactor where the change in conversion with respect to reactor volume is $0.001/V_T$. The total conversion up to this point is negligible, and the conversion in the first tube of the reactor section can be taken as 0.001.

(1) Figures 2 – 7 are the necessary working charts.

(2) Look up C_p and H_R at t = 1,109° F. and $a_n - \Delta a/2 = 0.0005$ conversion and tabulate in cols. 4 and 5 of Table 1

$C_p = 39.2$
$H_R = 37{,}000$

(3) Calculate ϕ/FC_p and $H_R\Delta a/C_p$ and enter in cols. 6 and 7.

$$\frac{\phi}{FC_p} = 48.1$$

$$\frac{H_R\Delta a}{C_p} = 0.94$$

(4) Calculate t_1 and enter in col. 8.

$$t_1 = t_E + \frac{\phi}{FC_p} - \frac{H_R\Delta a}{C_p}$$

$t_1 = 1{,}109 + 48.1 - 0.94 = 1{,}156°$ F.

(5) Look up k_1 on Figure 2 at 1,156° F. and enter in col. 9.

$k_1 = 3.35 \times 10^{-3}$

(6) Look up (P_F) for t = 1,156 and conversion 0.0005.

Calculate $2L'(P_F)$ and enter in col. 10.

$2L'\ P_F = (2)(44)(1.14) = 100$

Subtract from $(P_E)^2$ tabulated for $N_R = 0$

$P_1^2 = 3{,}240 - 100 = 3{,}140$

(7) Enter P_1 in col. 11.

$P_1 = \sqrt{3{,}140} = 56.0$

(8) Look up $(1-a)/(1+n_i+\delta a)$ at $a_1 = 0.001$ and enter in col. 12.

$$\left(\frac{1-a}{1+n_i+\delta a}\right)_1 = 1.0$$

(9) Calculate

$$y_1 = \frac{V_T}{F}(\text{col. 9})(\text{col. 11})(\text{col. 12})$$

$$y_1 = \frac{2.24}{159}(3.35 \times 10^{-3})(56.0)(1.0)$$

$y_1 = 0.00264$

Enter in first line of col. 13.

(10) Enter $1.5y_1$ in second line.
$1.5y_1 = 0.00396$

(11) Enter $y_o/2 = 0.0005$ in third line.

(12) Subtract $y_o/2$ from $1.5y_1$ and enter as Δa.

$\Delta a = 0.00396 - 0.0005 = 0.00346$

(13) Calculate a_2 and $(a_2 - \Delta a/2)$

$a_2 = 0.001 + 0.00346 = 0.00446$

$$a_2 - \frac{\Delta a}{2} = 0.00273$$

The tabulation should now appear as shown in Table 1.

Repeat these steps for succeeding tubes until $t_n > 1{,}475°$ F.

The results are plotted as points on Figure 8. The solid line was obtained by trial-and-error stepwise integration as outlined by Fair and Rase. The final results are as follows:

	TRIAL-AND-ERROR STEPWISE INTEGRATION	NUMERICAL INTEGRATION
temperature	1,475° F.	1,475° F.
pressure	23.0 lb./sq.in.abs.	24.5 lb./sq.in.abs.
conversion	65.5%	64.0%
total no. tubes	34.2	34.0

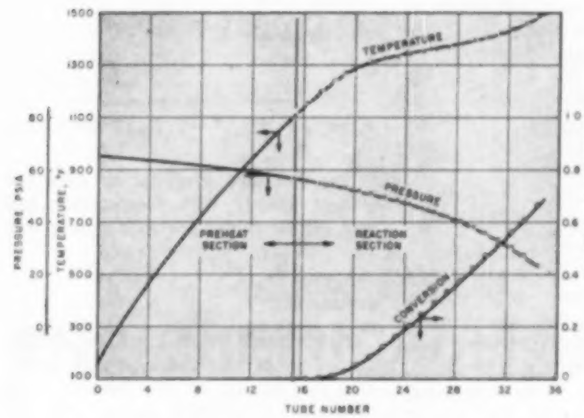


Fig. 8. Calculated curves for propane cracking unit.

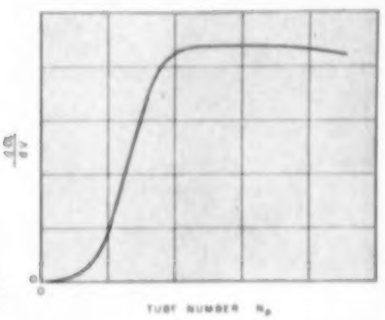


Fig. 9. Change of conversion rate in reaction section—typical.

Derivation of Design Equations

PREHEAT SECTION

Fair and Rase (*1*) have shown for a first-order reaction

$$\frac{d\alpha}{dV} = \frac{kP(1-\alpha)}{F(1+n_i+\delta\alpha)} \qquad (7)$$

Let the end of the preheat section be defined as that point at which, for the case of $\alpha = 0.001$,

$$\frac{d\alpha}{dV} = \frac{0.001}{V_T}$$

Hence

$$\frac{0.001}{V_T} = \frac{k_E(1-0.001)P_E}{F(1+n_i+0.001\delta)}$$

Neglecting the $(0.001)^2$ terms, and neglecting 0.001 as compared to 1.0,

$$k_E = \frac{(0.001)F(1+n_i)}{(V_T)(P_E)} \qquad (8)$$

The temperature at the end of the preheat section is that temperature corresponding to k_E. The pressure at the end of the preheat section must be assumed in order to solve this equation, and this assumption then can be checked by a calculation of the pressure drop.

Pressure drop may be represented by the following equation (*2*).

$$\frac{-dP}{dL} = \frac{0.0235}{D^{4.8}}\left(\frac{W}{1{,}000}\right)^{1.8}\frac{\mu^{0.2}}{\rho} \qquad (9)$$

$\frac{dP}{dL}$ = pressure drop/ft. of equivalent pipe length (lb./sq.in./ft.)

A heat balance around the preheat section gives

$$\phi N_E = F(C_p)_{avg.}(t_E - t_o) \qquad (10)$$

then

$$N_E = \frac{F(C_p)_{avg.}(t_E - t_o)}{\phi} \qquad (3)$$

but

$$L = N_E L' = \frac{FC_{p\,avg.}L'(t_E - t_o)}{\phi}$$

$$\text{or } dL = \frac{F(C_p)_{avg.}L'}{\phi} = dt \qquad (11)$$

$$\text{also } \rho = \frac{PM_o}{RT} \qquad (12)$$

The correct average C_p can be determined by observing that

$$(C_p)_{avg.}(t_E - t_o) = \int_{t_o}^{t_E} C_p dt$$

Numerically integrating the right side by means of Simpson's ⅓ rule yields

$$(C_p)_{avg.}(t_E - t_o) = \left(\frac{t_E - t_o}{6}\right)[(C_p)_o + 4(C_p)_a + (C_p)_E]$$

$$\text{or } (C_p)_{avg.} = \left[\frac{(C_p)_o + 4(C_p)_a + (C_p)_E}{6}\right] \qquad (13)$$

where t_a is the mid temperature, or

$$t_a = \frac{t_E + t_o}{2}$$

Combining Equations (9), (11), and (12),

$$-\int_{P_o}^{P_E} PdP = \left[\frac{F(C_p)_{avg.}L'}{\phi}\right] \times \int_{t_o}^{t_E}\left(\frac{0.0235}{D^{4.8}}\left(\frac{W}{1{,}000}\right)^{1.8}\frac{\mu^{0.2}RT}{M}\right)dt \qquad (14)$$

It is convenient to use P_F defined by

$$-dP = \frac{(P_F)dL}{P} \qquad (15)$$

This factor will be plotted vs. temperature and as a function of conversion.

$$P_F = \left[\frac{0.0235}{D^{4.8}}\left(\frac{W}{1{,}000}\right)^{1.8}\frac{\mu^{0.2}RT}{M}\right] \qquad (16)$$

Hence

$$-\int_{P_o}^{P_E} PdP = \frac{F(C_p)_{avg.}L'}{\phi}\int_{t_o}^{t_E} P_F dt \qquad (17)$$

It will be seen that P_F varies nearly linearly with temperature at a constant composition and therefore the integral may be approximated closely by

$$\int_{t_o}^{t_E} P_F dt = \left[\frac{(P_F)_E + (P_F)_o}{2}\right](t_E - t_o) \qquad (18)$$

Substituting this into Equation (17) and integrating the left side yields Equation (19) at bottom of page.

The number of tubes in the preheat section can be calculated by using Equation (10)

$$N_E = \frac{F(C_p)_{avg.}}{\phi}(t_E - t_o)$$

Note that due to the definition of the preheat section, the number of tubes may not be an integral number.

REACTION SECTION

Let $\Delta\alpha$ equal the change in conversion which occurs in the volume of one tube and bend. It has been observed that for tubular reactors $d\alpha/dV$ changes in the reaction section as indicated by Figure 9.

$$P_E = \sqrt{P_o^2 - \frac{[(P_F)_E + (P_F)_o]F(C_p)_{avg.}L'(t_E - t_o)}{\phi}} \qquad (19)$$

For the straight-line portions of the curve, $(da/dV)_{avg.}$ for a tube is equal to (da/dV) at the center point of that tube. Furthermore, for the straight-line portions, (da/dV) at the center of a tube is equal to (da/dV) at the beginning of the tube (this is, of course, the exit of the previous tube and bend) + ½ the change in (da/dV) for the previous tube and bend.

$$\left(\frac{da}{dV}\right)_{avg.} = \left(\frac{da}{dV}\right)_n + \frac{1}{2}\left[\left(\frac{da}{dV}\right)_n - \left(\frac{da}{dV}\right)_{n-1}\right]$$

$$\left(\frac{da}{dV}\right)_{avg.} = \frac{3}{2}\left(\frac{da}{dV}\right)_n - \frac{1}{2}\left(\frac{da}{dV}\right)_{n-1}$$

Since

$$\left(\frac{da}{dV}\right)_{avg.} = \frac{\Delta a}{V_t}$$

and

$$\left(\frac{da}{dV}\right)_n = \left[\frac{kP(1-a)}{F(1+n_i+\delta a)}\right]_n,$$

from Equation (7),

then for tube $n+1$

$$\Delta a = \frac{3}{2}\left[\frac{kPV_T(1-a)}{F(1+n_i+\delta a)}\right]_n - \frac{1}{2}\left[\frac{kPV_T(1-a)}{F(1+n_i+\delta a)}\right]_{n-1} \quad (20)$$

The numerical integration then is exact for straight-line portions of Figure 8, and this represents the greatest portion of the reaction section. If the increments are small, the error introduced at the curved portions is small.

A heat balance around the tube under consideration gives: (increased sensible heat) = (heat added by furnace) − (endothermic heat of reaction)

$$F(C_p)\Delta t = \phi\Delta N - H_R F\Delta a$$

$$\Delta t = \left(\frac{\phi\Delta N}{FC_p}\right) - \left(\frac{H_R}{C_p}\right)\Delta a \quad (21)$$

This permits the calculation of Δt if Δa is known. C_p changes only slightly along any tube and little or no error is introduced by using that value corresponding to the entrance temperature for the average C_p. The differential heat of cracking, however, may change considerably owing to the change in the composition of the gas stream. A suitable average value is that value corresponding to the entrance temperature t_{n-1} and the average conversion $(a_n - \Delta a/2)$

The pressure drop equation yields

$$-\Delta P = \frac{(P_F)L'\Delta N}{P_{avg.}} \quad (22)$$

where

$$-(\Delta P) = P_{n-1} - P_n$$

Since the increments are small, $P_{avg.}$ can be represented as

$$P_{avg.} = \left(\frac{P_n + P_{n-1}}{2}\right)$$

Then by substituting into Equation (22) and rearranging

$$(P_{n-1} - P_n)\left(\frac{P_{n-1}+P_n}{2}\right) = (P_F)L'\Delta N$$

or

$$P_n = \sqrt{P_{n-1}^2 - 2(P_F)L'\Delta N} \quad (23)$$

The pressure drop factor does not change greatly with temperature and can be determined for tube n at t_n and $(a_n - \Delta a/2)$.

Conclusion

The preheat section can be defined arbitrarily as long as there is no significant conversion in this section. The definition which was chosen ends the preheat section before there is a significant total conversion, but near the point at which an appreciable rate of reaction begins. By the use of the numerically integrated average C_p and average P_F, results for the preheat section approach the accuracy of an analytical integration.

The results of the stepwise numerical integration over the reactor section will approach the "exact" solution if sufficiently small steps are taken. It has been observed that excellent agreement between this method and the trial-and-error method can be obtained if increments of one tube and bend are chosen. The method is flexible and may be adapted easily to cases in which the heat flux varies along the reactor. As the illustrative problem shows, it is also particularly applicable where heat of cracking varies rapidly.

Notation

C_p = specific heat (B.t.u./° F.-lb. mole key reactant fed)
D = internal diameter of tubes (in.)
F = feed rate of key reactant (lb.moles/hr.)
H_R = differential heat of cracking (B.t.u./lb.mole converted)
k = reaction velocity constant (lb.moles/hr.-cu.ft.-lb./sq.in.abs.)
k_E = reaction velocity constant at end of preheat section (lb.moles/hr.-cu.ft.-lb./sq.in.abs.)
L = equivalent length of tubing
L' = equivalent length of one tube and bend, (ft.)
M = molecular weight
M_o = molecular weight of the feed
N = number of tubes
N_E = number of tubes in preheat section
n_i = moles of inerts/mole key reactant entering
P = pressure, lb./sq.in.abs.
P_E = total pressure at end of preheat section (lb./sq.in.abs.)
P_F = pressure drop factor (defined by Equation (16))
P_o = inlet pressure, lb./sq.in.abs.
P_1 = pressure at entrance of tube
P_2 = pressure at exit of tube
R = gas constant (10.73 lb./sq.in.abs.-cu.ft./° R.-lb. mole)
t = temperature (° F.)
t_o = inlet temperature (° F.)
T = temperature (° R.)
V_T = volume of one tube and bend (cu.ft.)
W = mass rate of flow (lb./hr.)

GREEK LETTERS

a = fractional conversion
δ = increase in the number of moles/mole converted (expansion factor)
μ = viscosity (micropoise)
ρ = density (lb./cu.ft.)
ϕ = heat flux (B.t.u./hr.-tube and bend). This heat is supplied by the furnace.

SUBSCRIPTS

a = conditions at the arithmetic average temperature between t_E and t_o
E = conditions at end of preheat section
n = conditions at inlet point of tube n in the reaction section (see Figure 1)
$n-1$ = conditions at inlet point of tube preceding tube n
$n+1$ = conditions at inlet point of tube following tube n
o = inlet conditions
R = reaction section

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THE CHEMICAL TREATMENT OF COTTON AND WOOL

Gilbert E. Goheen and A. Mason DuPré, Jr. | **Southern Regional Research Laboratory, New Orleans, Louisiana †**

Although the chemical finishing of natural fibers has been an important part of the textile industry for many years, such operation has become much more important during the past decade or so. This has resulted from at least two factors: (1) increased scientific knowledge of the chemistry and physics of the natural fibers, and (2) the increased competition afforded the natural fibers by the synthetics.

Chemical Treatment of Cotton

The following are some performance characteristics which if enhanced would improve cotton for many uses:

- wrinkle resistance
- luster resistance
- heat stability
- faster drying
- water repellency
- dimensional stability
- flame resistance
- antisoiling
- antistaining
- improved rot and weather resistance

† A laboratory of Southern Utilization Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

A broad approach to the problems involved in improving the properties of cotton is being made in many laboratories including those in the Southern Utilization Research Branch of the Agricultural Research Service.

Cellulose, which comprises on the average 94% of cotton, is composed of polymers of anhydroglucose units. Most of these units contain two secondary hydroxyl groups and one primary hydroxyl group. The anhydroglucose units are combined through 1,4-oxygen linkages. This linkage is easily destroyed by acid but is fairly stable to alkali in nonoxidative media. The physical make-up of the cotton fiber is also an important factor.

In addition to the chemical and physical factors of the cotton fiber, the chemical treatment of cotton fabric in many cases is influenced by the type of fabric construction. This may be true especially in the application of a crease-resistant finish. Consequently increased coordination between research on fabric construction and research on the resin treatment of cotton is now taking place.

The chemical treatment of cotton may be divided into two types:

1. purification and finishing of natural cotton,
2. chemical modification and other chemical treatments of cotton fiber with retention of fibrous form.

Some steps falling in these two categories may be briefly summarized as follows:

1. Purification and Finishing of Natural Cotton

a. SIZING AND DESIZING

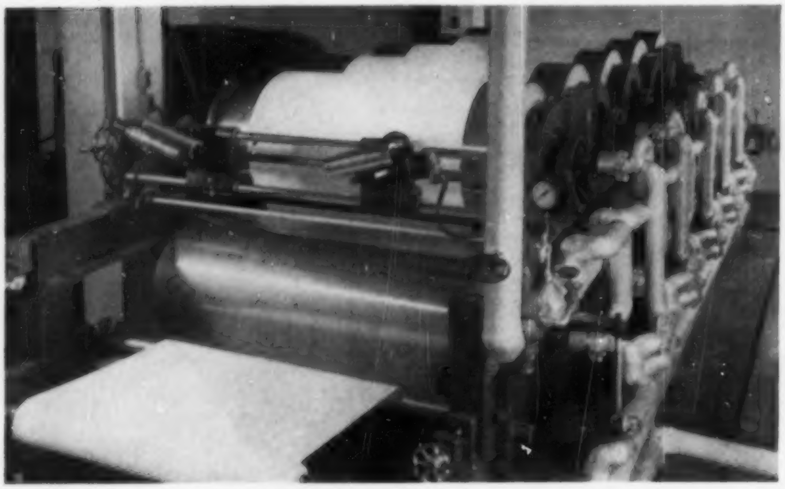
Although many synthetic water-soluble polymers have been proposed as sizing materials, most of these have not been used to any large extent owing to the fact that they cost more than starch, that is, starch in a price range of 5 to 10 cents/lb.

b. SCOURING

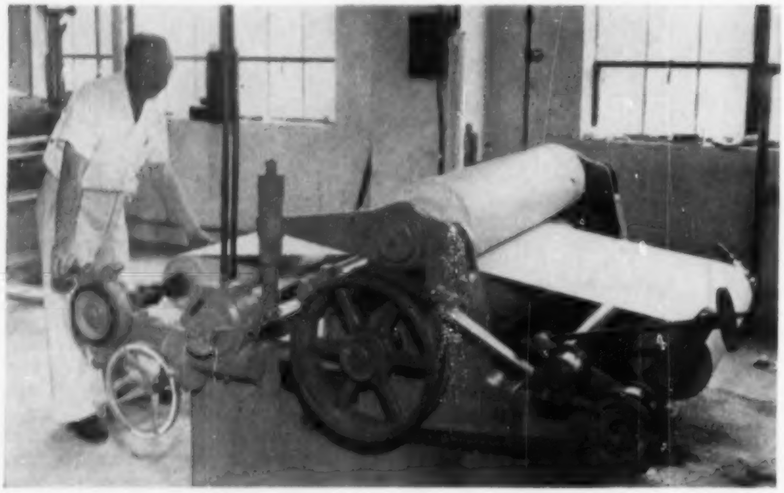
Sodium hydroxide in concentrations of 1-3% is used at temperatures of 100-125° C. for several hours.

c. BLEACHING

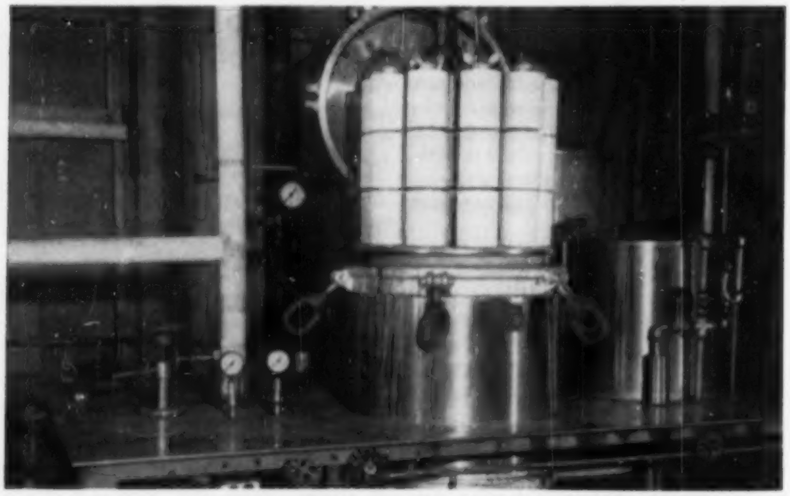
Cloth is run continuously through



Cotton fabric being dried on heated rolls after aminization to impart ion-exchange properties.



Lead chromate being applied to cotton fabric, using padder rolls, to increase its resistance to degradation by sunlight.



Packages of cotton yarn being removed, after processing, from batch pilot plant for the partial acetylation of cotton raw stock and yarn.

large stainless steel boxes which contain hydrogen peroxide or hypochlorite bleach. Detergents, sequestering agents, and in some cases optical brightening agents may be included at this stage to provide a more uniform white product with fewer rejects due to stains, resistance spots, and rub marks.

d. MERCERIZING

Luster, strength, and higher absorbency and susceptibility to dyes are imparted by a low-temperature treatment of either yarn or cloth under tension with 20-25% sodium hydroxide solution.

e. DYEING AND PRINTING

Vat dyes find wide application. Naphthol dyes, many direct dyes, sulfur colors, and a variety of other types of dyes are available for use, and dye manufacturers are continually carrying out research to provide better dyestuffs and better methods of application.

f. FINISHING

Optical brightening agents provide brilliance to the finished products. Softening agents such as sulfated oils, cationic softeners, and many brand materials are available which provide a better feel to the touch. Water-soluble gums, starches, and water-soluble polymers provide stiffness or body to cottons. Some cellulose ethers, such as carboxymethylcellulose and hydroxyethyl and methyl cellulose have been used as well as polyvinyl alcohol, polyvinyl acetate, polystyrene, urea- and melamine-formaldehyde resins, rubber latices, and many other types. Some of these treatments are making possible so-called wash-and-wear cotton fabrics which require little or no ironing.

Other finishing agents have been proposed to provide additional absorbency, or resistance to abrasion, shrinkage, mildew, light, water, flame, and creasing. These agents may have various degrees of durability.

2. Chemical Modification and Other Chemical Treatments of Cotton Fiber with Retention of Fibrous Form

In this class may be included both treatments that cause a change in the chemical structure of the cotton cellulose and those that add chemical substances to the cotton in a relatively permanent manner.

a. PARTIALLY ACETYLATED COTTON

An outstanding example of the chemical modification of cotton to produce an entirely new fiber is partially acetylated cotton (PA cotton), the first practical

fibrous cotton with new properties developed for American industry at the Southern Regional Research Laboratory of the U.S. Department of Agriculture's Agricultural Research Service. It is made by treating cotton with acetic anhydride in the presence of perchloric acid as a catalyst. The fabric is in commercial production.

The product is believed to consist of crystalline cellulose with interspersed cellulose triacetate, numerically averaging grossly about one acetyl per glucose unit (21% acetyl by weight).

PA cotton has an appearance, color, strength, and texture much like ordinary cotton. It is odorless and nontoxic. However, in many respects it is better than regular cotton. It has a definitely increased heat endurance, as much as an eightfold gain. In actual performance tests in laundry-press-pad covers, PA cotton exhibits four to five times the life of ordinary cotton.

It has excellent mildew and rot resistance. Under accelerated soil burial tests in which untreated cotton loses practically all its strength in one week, PA goods will retain 80-100% strength for longer than fifty weeks. Similarly striking results are obtained upon exposure in ocean water with fishing nets and in sand-bag tests.

Other respects in which PA cotton excels or differs are resistance to acids and to certain other chemicals, better drying rate, increased electrical resistance, and soil resistance. Whereas tear strength and flex abrasion of PA cotton fabrics are lower than regular cotton, these deficiencies may be largely overcome by fabric design or by the use of suitable softening agents. Recent studies have shown that a cotton yarn or fabric which has been dyed with certain vat dyes before partial acetylation displays unusually good sunlight and weather resistance.

b. CYANOETHYLATED COTTON

Cyanoethylated (CN) cotton is an example of a chemically modified cotton produced by etherification with the use of acrylonitrile. Due in part to the recent commercial availability of this reagent in large quantities at relatively low cost, there is considerable research and development activity at the present time with this material. Performance tests are underway to determine whether CN cotton has any real advantages over PA cotton.

c. FLAME-RESISTANT COTTON CLOTH

An improved flame-resistant treatment for cotton fabric has been developed recently at the Southern Regional Research Laboratory in cooperation with the Army Quartermaster Corps' Research and Development Command. Two improved methods of imparting flame resistance to cotton cloth were announced previously by USDA's Southern Utilization Research Branch.

The THPC process utilizes a unique chemical tetrakis(hydroxymethyl)phosphonium chloride, which reacts with certain other materials to form an insoluble polymer within the fiber. The second process uses a bromoform-allylphosphate (BAP) material. Applied in emulsion form to cotton fabrics, it coats each fiber with an insoluble polymer. These earlier processes give a durable finish. Fabrics treated by either method are flame- and glow-resistant, and useful for many purposes. They each pass the usual test of not propagating flame when the center of a swatch of the treated cloth is exposed to an open flame. However, when both treatments are properly applied to the same cloth, the combination is much more effective than when either is used alone. The resulting product will pass the much more stringent "strip-burning test," in which a thin strip of fabric, instead of the wider swatch, is exposed to an open flame.

In the new combination treatment, one part of BAP emulsion is mixed with two parts of the THPC-resin solution and applied in a one-bath treatment. The cloth is impregnated with the mixture, then dried, and heat cured. This process increases the weight of the cloth about 18%, but normal fabric properties are otherwise little changed. The flame-resistant finish is highly durable to both laundering and dry-cleaning.

d. LEAD CHROMATE TREATED COTTON

A simple, economical treatment of cotton with lead chromate results in a cotton, tobacco-shade cloth which has saved some tobacco growers an estimated $200/acre each season they have used it over their fields.

The original procedure developed passes cloth through a 3.5% lead acetate bath, squeezes, and then passes through a second bath of 1.4% sodium dichromate. The cloth is then washed and dried. Another process being used consists of applying the lead chromate directly by means of an alkyd resin binder. This year about 5,000,000 sq.yd. will be going into a second or a third year's use, and an additional 3-4,000,000 yd. will be put out for the first time.

Growers report that treated cloth is usable three seasons as top cover, without replacements. It then retains about a quarter of its strength. In contrast, untreated cloth usually falls to pieces after only one season out of doors. The problem which was overcome was primarily that of the photochemical action of sunlight.

Chemical Treatment of Wool

Wool, like cotton, undergoes two kinds of chemical treatments in processing: (1) those concerned with converting raw wool into finished fabric, and (2) those that improve the properties of the fiber and fabrics. Under the impetus of competition from synthetic fibers, increasing attention is being given to processes in the second group. At the same time many improved procedures in wool-manufacturing operations such as scouring, carbonizing, bleaching, fulling, setting and dyeing, have resulted as a consequence of increasing knowledge of the molecular structure and chemical reactivity of wool. A brief summary of the chemical nature of wool may help to make a description of these recent developments more understandable.

The substances of which wool consists belong almost entirely to the complex chemical group known as proteins, which comprise many different amino acids combined into long peptide chains. Wool proteins belong to the keratin group, characterized by a high-sulfur content which is derived mainly from the amino acid cystine. In the wool fiber the peptide chain molecules lie more or less parallel to its length, the chains being bridged by cystine residues to form disulfide cross-links. These disulfide cross-links make an important contribution to both the mechanical properties and chemical reactivity of wool. They are readily oxidized, reduced, and hydrolyzed to give a variety of reaction products.

In addition to the disulfide bond, the free amino, carboxyl, hydroxyl, and amide groups present in various side groups of the main peptide chain are important sites of chemical reactivity.

1. CONVERSION OF RAW WOOL INTO FINISHED FABRIC

Many improved procedures have been developed to reduce the extent of fiber degradation by chemical reagents in ordinary wool processing.

For example, in *raw wool scouring*, the trend is toward use of nonionic detergents under neutral conditions, replacing traditional use of soap and alkali. In *bleaching* wool with hydrogen peroxide, a recently developed pretreatment of wool with formaldehyde is reported to minimize fiber damage. Formaldehyde has also been proposed as a protective agent in *high-temperature dyeing of wool*.

Another important advance in dyeing methods is the introduction of premetalized dyestuffs, which can be applied to wool from neutral solution, in contrast to the acid bath traditionally used.

2. IMPROVEMENT OF PROPERTIES OF WOOL FIBER AND FABRICS

a. Shrink resistance

The two distinct kinds of shrinkage should be noted: (1) relaxation shrinkage produced simply by soaking in warm water, releasing strains set up during manufacture, and (2) felting shrinkage produced by mechanical agitation of a fabric as in laundering, bringing about matting and entanglement because of fiber migration. The felting property of wool depends on the scalelike structure of the fiber surface, which has greater friction on the tip-to-root (antiscale) than in the root-to-tip (with-scale) direction. The resulting differential friction effect combined with fiber resiliency causes adjacent fibers to travel rootward when rubbed.

The chemical treatment of wool to produce shrink resistance is concerned primarily with the prevention of felting. Commercial processes now in use either degrade the fiber surface to reduce the differential friction effect or introduce resins which cement the fibers within the yarn and cloth structure and thereby prevent relative fiber movement.

Processes causing surface degradation depend on controlled breakdown of disulfide linkages in the scale structure. Most successful treatments use chlorine, usually in the form of sodium hypochlorite. Another chlorination technique is the treatment of dry wool with gaseous chlorine or solid bleaching powder, restricting chlorination to the surface and reducing the extent of fiber damage. Chemical processes of more limited importance use alcoholic potash, enzymes, potassium permanganate, hydrogen peroxide, and peracetic acid, often in combination with chlorination.

Deposition of resins or polymers on or in wool fiber is the second, and potentially the more desirable, method of shrinkproofing. In contrast to chemical surface degradation, these processes impart shrinkage resistance with little if any fiber damage. In some instances they may even improve the wear resistance, water repellency, and soil resistance. In spite of these advantages, acceptance of polymer treatments has been hampered by cost considerations and by impairment in handle of the fabric generally associated with resin deposition.

Among the more promising of many new methods for shrinkage control by polymer deposition are those which make use of N-methoxymethyl nylon, organosilicon polymers, and formaldehyde-hardened casein.

b. Mothproofing

Another well-known shortcoming of wool is its susceptibility to attack by moths and beetles. As a consequence many chemical treatments have been developed to protect wool from these insects. Mothproofing treatments having practical application have commonly used inorganic fluorides and silicofluorides, DDT, and chlorinated aromatic sulfonic acid derivatives. Silicofluorides and DDT have been applied in various synthetic resins to improve fastness. In addition, certain insecticides, which combine chemically with wool, have been used for permanent mothproofing.

c. Wear resistance

Methods of increasing the wear resistance of wool are based on formation of polymers on the surface and within the fiber. The first process of this type applied anhydrocarboxyglycine in organic solvent under conditions such that polyglycine was formed. The previously mentioned N-methoxymethyl nylon and organosilicon treatments, in addition to imparting shrinkage resistance, also increase the wear resistance of wool.

d. Water repellency

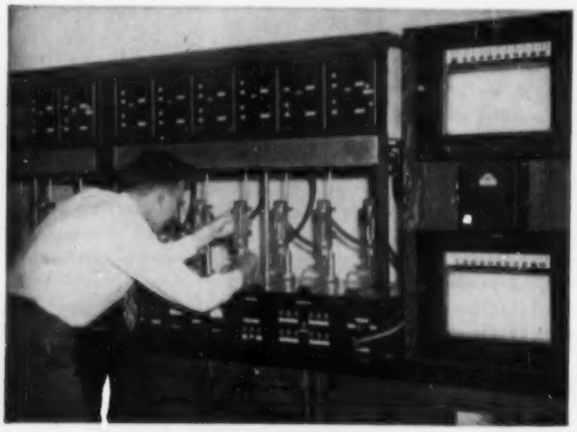
Methods of improving the water repellency of wool are similar to those used for other fibers, for example, use of silicones. Until recently these materials were considered unsuitable for wool because the curing temperatures required, 300° F. and above, were much too high for wool. Better catalysts have now permitted development of finishes, especially designed for wool, that cure at 250° F.

e. Permanent set

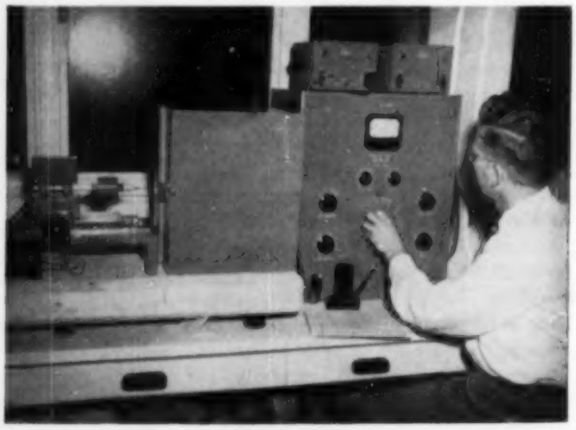
Mention should be made of chemical treatments for producing permanent set in wool. These involve first breaking the disulfide bonds with reducing agents to release internal stresses, shaping the fabric, and then imparting a permanent set to the fibers by rebuilding cross-links with oxidizing agents. Such techniques have found practical application mainly in the cold-wave preparations for women's hair. Moreover, the principle of chemical set is important for the manufacture of pleated garments and for curling or crimping wool and other uncrimped animal fibers.

Acknowledgment

The assistance of Willie Fong of the Protein Section, Western Utilization Research Branch, USDA Agricultural Research Service, in obtaining information on wool is greatly appreciated.



Adjusting apparatus for recording tension in individual stretched wool fibers, for studying effects of chemical treatments on fiber mechanical properties.



Trial model of apparatus to evaluate noise made by rubbing wool fabric to explore possible relationships to fabric stiffness and similar properties.

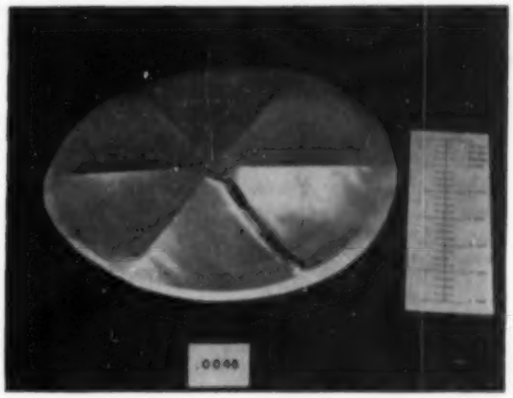


Fig. 6a. A 0.0045-in. thick 2S-H18 aluminum rupture disc that failed under vacuum.

when frequently recurring overpressure is to be relieved

aluminum foil rupture discs offer low-cost protection

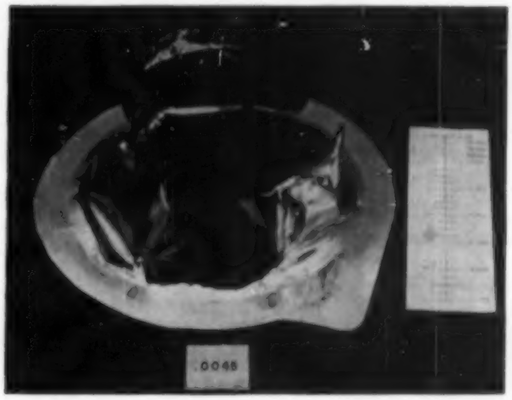


Fig. 6b. Typical 0.005-in. thick 2S-H18 aluminum rupture disc after positive failure.

Paul B. Stewart
and Robert T. Fox, Jr.
University of California
Berkeley, California

Rupture discs were developed in this country for the chemical and petroleum refining industries as a replacement for safety valves or relief valves which were not satisfactory in some kinds of chemical service because: (1) corrosion would make such valves undependable, either causing premature pressure relief or "freezing" them so that they could not function, (2) such valves are extremely expensive when made of some materials resistant to corrosion, and (3) they offer a major resistance to flow and quick pressure relief. Rupture discs were recognized in the 1944 Addenda to the Unfired Pressure Vessel Code by the American Society of Mechanical Engineers, and are now widely used in industry (*A*).

At least three firms (Black, Sivalls and Bryson of Kansas City, Missouri, Baker and Company of Newark, New Jersey, and Frangible Discs, Inc., of Penns Grove, New Jersey) manufacture rupture discs and offer them for sale as commercial products.

Industrial rupture discs are usually preformed to a spherical shape to put the material completely in tension. If the disc is to be subjected to vacuum as well as positive pressures, a vacuum support to prevent reverse flexure is used. The usual design of vacuum supports is a hemispherical structure to fit snugly under the rupture disc, with some three to six diametral slots cut into it; the resulting segments are held together at their apices at the center of the pipe. Commercial practice calls for cutting a number of rupture discs from the same sheet of metal, bursting some of them, and rating those remaining at the average bursting pressure of those tested.

Information that can be obtained from the catalogs of commercial rupture-disc manufacturers (*1, 2*) consists of a general idea of the relation between material of construction and pipe (or flange) diameter and bursting pressure. Noticeably and understandably missing from these data is any mention of thickness of the sheet metal or its properties.

Two articles by Murphy of Black, Sivalls and Bryson (*9, 10*), and one by Prescott of the Du Pont Company (*11*) comprise the periodical literature on commercial rupture discs.

Commercially available rupture discs are designed for the emergency relief of overpressure in chemical reaction vessels and other pressure vessels. Because of the nature of the service, overpressure and consequent disc failure with subsequent replacement are expected to occur but only rarely. Therefore, the cost of approximately $15 for rupture disc and vacuum support rated to burst at 18 to 22 lb./sq.in. gauge is a relatively minor matter.

At present R. T. Fox, Jr., is Lieutenant (j.g.), U. S. Navy, Naval Ordnance Test Station, China Lake, California.

Table 1.—Experimental Results

Flat Aluminum Foil Rupture Discs

Tank size (nominal) (in.)	Rupture disc thickness (in.)	temper	Bursting pressure (lb./sq.in. gauge) gradual load from 1 atm.	from vacuum	impact load from 1 atm.	from vacuum
2	0.001	0	4	..	..	..
		H-18	13	..	..	..
	0.002	0	18	18	19	19
	0.003	0	43	44	41	42
		H-18	40	31	38	33
	0.0045	0	60	62	58	56
	0.005	0	64	66	63	62
	0.001	0	2	..	..	..
		H-18	4	..	..	..
4	0.002	0	7	..	9	..
	0.003	0	21	21	21	21
		H-18	18	13	18	12
	0.0045	0	30	31	28	28
	0.005	0	31	32	32	32
		H-18	48	47	46	34
	0.008	0	69	69	67	65
	0.010	0	83	83	83	80
		H-18	80	80	80	89
6	0.001	0	1	..	..	..
		H-18	3	..	..	..
	0.002	0	5	..	..	..
	0.003	0	15	15	15	15
		H-18	12	..	10	..
	0.0045	0	21	20	19	18
	0.005	0	22	23	20	20
		H-18	30	35	28	28
	0.008	0	47	47	47	43
	0.010	0	57	57	57	53

1. temper designations: 0 = dead soft.
H-18 = full hard
2. .. indicates no test possible.

Table 2.—Effect of Vacuum Preloading

Tank size (nominal) (in.)	Rupture disc thickness (in.)	temper	Vacuum bp* — no vacuum bp* (lb./sq.in. gauge) gradual	impact
2	0.002	0	0	0
	0.003	0	1	1
		H-18	−9	−5
	0.0045	0	2	−2
	0.005	0	2	−1
4	0.003	0	0	0
		H-18	−5	−6
	0.0045	0	1	0
	0.005	0	1	0
		H-18	−1	−12
	0.008	0	0	−2
	0.010	0	0	−3
		H-18	0	9
6	0.003	0	0	0
	0.0045	0	−1	−1
	0.005	0	1	0
		H-18	5	0
	0.008	0	0	−4
	0.010	0	0	−4

Table 2.—Summary

loading	Gradual		Impact	
temper	0	H-18	0	H-18
bursting pressure				
change ± 2 lb.	14	2	11	1
increase > 2 lb.	0	1	0	1
decrease > 2 lb.	0	2	3	3

* vacuum bursting pressure minus no vacuum bursting pressure.

Contrasted to such seldom-occurring conditions are those experienced in a research program just completed in which failure of a rupture disc could be expected two to three times a day over a period of perhaps six months. Using those commercially available would mean a minimum expenditure of $1,500, a substantial portion of the operating budget. Since the expected life of the discs was a matter of hours rather than months or years, it was believed that flat sheets of aluminum foil, at a cost of a few cents each, clamped between pipe flanges would serve this purpose as well as commercial rupture discs. Because such discs are indeterminate structures, theoretical mechanics cannot be used in their design. Experimental data were not available.

Theoretical Studies

Although a diaphragm rigidly clamped on its entire periphery is an indeterminate structure as mentioned previously in this paper, some theoretical studies have been made of the deformation of such bodies under certain types of loading. Most of these studies originated with the U. S. Navy during World War II and were concerned with the general problem of damage to the hulls of ships and other objects from underwater explosions. A résumé of these declassified reports follows.

John Kirkwood (*7*) has worked out a solution to the problem of parabolic deformation of a thin, circular diaphragm clamped around its edge. He developed an equation relating the deflection in the center of the diaphragm necessary to cause rupture, the radius of the diaphragm, and the critical rupture elongation of the material in tension.

E. H. Kennard (*6*) investigated the combined effects upon a circular diaphragm of a shock wave produced by an underwater explosion and the motion of the surrounding structure. He has photographic evidence to support his contention that the characteristic deflection of a thin diaphragm is more or less spherical for static or slowly applied loads (no cavitation near the plate), and is conical for the suddenly applied load of an underwater explosion when cavitation is probably present.

Whether a material work-hardens or not was related to the deformation shape of a circular diaphragm by G. E. Hudson (*4*). He assumed loading to start at the periphery and progress symmetrically toward the center, and he developed equations for this case. His conclusions were that materials that work-harden become spherical and that other metals become conical.

Another report by Hudson (*5*) gives the results of underwater explosion tests on a 10-in. diam., air-backed, steel diaphragm 0.57 in. thick. The pressure-time history is composed of (1) a nearly instantaneous, initial, high pressure rise

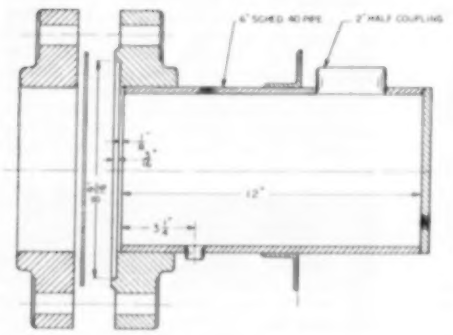


Fig. 2. 6-in. test tank.

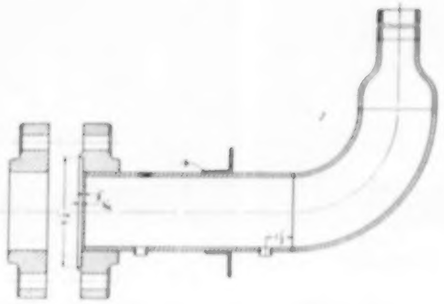


Fig. 3. 4-in. test tank.

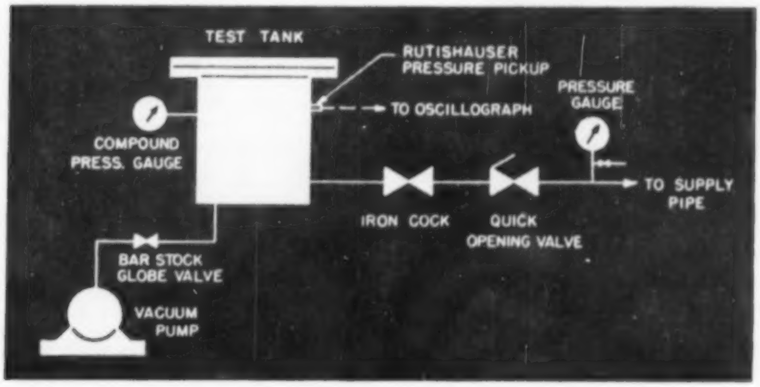


Fig. 1. Experimental installation.

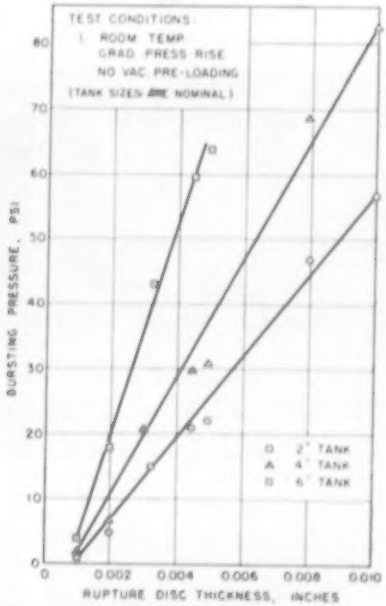


Fig. 7. Bursting pressure vs. disc thickness for 2S-O aluminum.

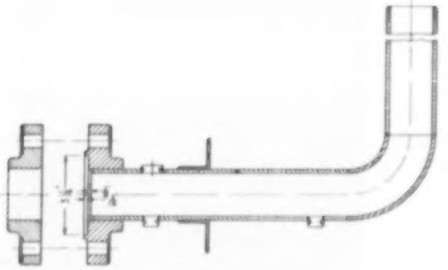


Fig. 4. 2-in. test tank.

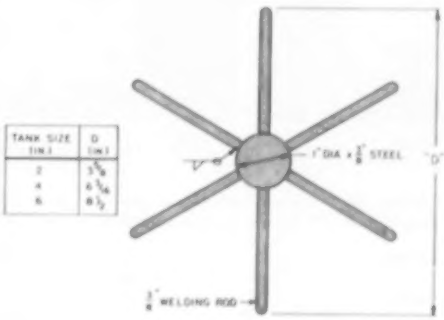


Fig. 5. Spoke vacuum support.

Table 3.—Effect of Impact Loading

Tank size (nominal) (in.)	Rupture disc thickness (in.)	temper	* Impact bp—gradual bp (lb./sq.in. gauge) no vacuum	vacuum
2	0.002	0	1	1
	0.003	0	−2	−2
		H-18	−2	−2
	0.0045	0	−2	−6
	0.005	0	−1	−4
4	0.002	0	2	..
	0.003	0	0	0
		H-18	0	−1
	0.0045	0	−2	−3
	0.005	0	1	0
		H-18	−2	−13
	0.008	0	−2	−4
	0.010	0	0	−3
		H-18	0	9
6	0.003	0	0	0
		H-18	−2	..
	0.0045	0	−2	−2
	0.005	0	−2	−3
		H-18	−2	−7
	0.008	0	0	−4
	0.010	0	0	−4

* impact loading bursting pressure minus gradual pressure loading bursting pressure.

associated with the initial shock front, followed by (2) an exponential pressure decay, (3) a secondary pressure increase of longer duration, and (4) final pressure decay. Some of the experimental diaphragms appear to be nearly parabolic and others more nearly conical.

Gleyzal (*3*) developed a set of relations among deflection, circumferential and radial stress, and circumferential and radial strain as functions of the tensile properties of the material, the imposed pressure, the diameter, and thickness of the diaphragm. His curves approach parabolic shape.

Mintz (*8*) performed static deflection tests on copper and steel diaphragms. His curves of deflection plotted against pressure are approximately straight lines at low loads, becoming curved at the higher loads.

Experimental Equipment and Procedure

A schematic diagram of the experimental installation is shown in Figure 1. The construction of the three test tanks is specified in Figures 2, 3, and 4.

Table 4.—Effect of Disc Temper

Tank size (nominal) (in.)	Rupture disc thickness (in.)	2S-0 bp*—2S H-18 bp* (lb./sq.in. gauge) gradual: no vacuum	gradual: vacuum	impact: no vacuum	impact: vacuum
2	0.001	−9	..	..	..
4		−2	..	..	..
6		−2	..	..	..
2	0.003	3	13	3	11
4		3	8	3	9
6		3	..	5	..
4	0.005	−17	−15	−14	−12
6		−8	−12	−8	−8
4	0.010	3	3	3	−9

* 2S-0 temper disc bursting pressure minus 2S H-18 temper disc bursting pressure.

temper designations:
0 = dead soft
H-18 = full hard

.. indicates no test possible.

Even though the pipe flanges were machined after welding, some initial trouble was experienced due to sharp edges on the flanges tearing the foil and causing premature disc failure. This difficulty was eliminated by a slight rounding of the flange edges with abrasive cloth and careful subsequent handling of them to prevent their surfaces and edges being marred accidentally. The flange surfaces were given a light coating of Dow-Corning silicone vacuum grease.

Commercial aluminum foil was the only material tested as a rupture disc because of its low cost, ready availability, and satisfactory corrosion resistance. This was available in two tempers, 2S-0 (dead soft) and 2S-H18, in thicknesses from 0.001 to 0.010 in.

The aluminum foils tested were checked by spectrographic analysis for chemical composition, and all samples fell within the commercial specifications for alloy 2S. Physical testing of the foils was not attempted. Thicknesses were checked with a supermicrometer, which showed actual and nominal thicknesses to be identical.

The first vacuum support for the foil discs is shown in Figure 5. The result of using this vacuum support, insufficient support for the foil, is shown in Figure 6*a*. The second vacuum support was a disc cut from 4-mesh, 18-gauge woven wire screen, which proved adequate for the rupture-disc test program. This screen support, however, proved to offer too much flow restriction for relieving excessive pressures caused by the combustion of fuels, and was discarded. Thus, in the actual use of the rupture discs they were allowed to deform under vacuum and were in this "reverse" shape when the excess pressure was applied.

Figure 6b shows a typical disc after failure under positive pressure.

Two types of pressure-measuring instruments were used: (1) a Bourdon-tube vacuum and pressure gauge equipped with an auxiliary hand to indicate the maximum pressure reached, and (2) a Rutishauser pressure pick-up connected to an oscilloscope to give a pressure-time history of some of the tests.

A Fastax camera was used to obtain high speed motion pictures of the bursting process of the discs in several tests.

The bursting tests on the rupture discs were carried out in four different manners: (1) initial pressure atmospheric, pressure applied gradually, (2) initial pressure atmospheric, pressure applied suddenly (shock or better called impact loading), (3) initial vacuum, pressure applied gradually, and (4) initial vacuum, pressure applied suddenly.

These test procedures are outlined in detail in the following paragraphs:

1. Initial Pressure Atmospheric, Pressure Applied Gradually

After the test disc was bolted in the flange, air was admitted at approximately 1 lb./sq.in./sec. until failure of the disc. The maximum pressure sustained by the disc was shown by the maximum reading indicator on the compound pressure gauge. This process was repeated twice more to determine the rupture pressure.

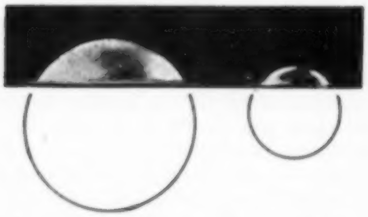


Fig. 8a. Profile of deformed aluminum discs that did not fail. Right: 0.003-in. thick, 2S-O; left: 0.008-in. thick, 2S-O.

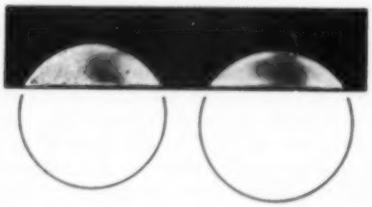


Fig. 8b. Profile of deformed aluminum discs that did not fail. Right: 0.010-in. thick, 2S-O; left: 0.008-in. thick, 2S-O.

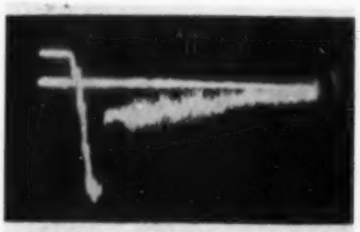


FIG. 9a

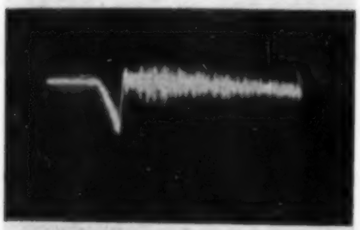
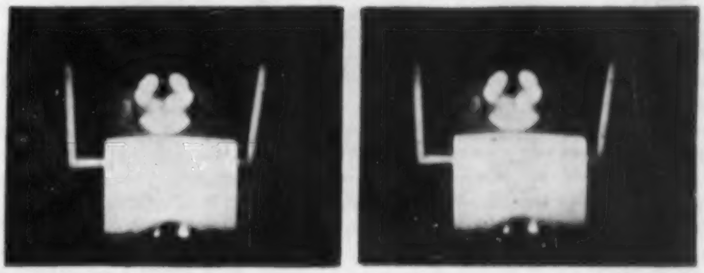


FIG. 9b

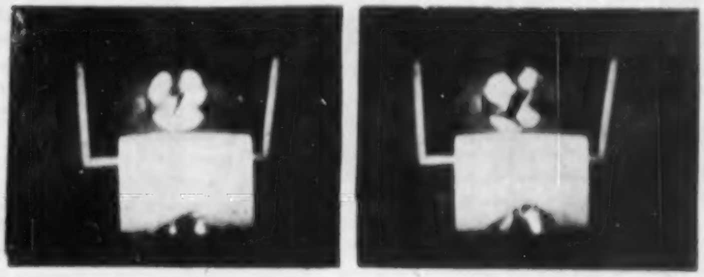
FIG. 9c

Fig. 9. a, b, and c. Pressure histories during rupture-disc failure; positive pressure is down and time increases to the right.



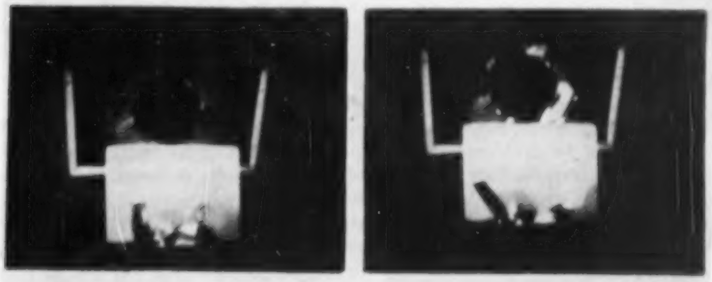
FRAME 1 FRAME 2

Fig. 10. Frames 1-4, 7, 9. Failure of 6-in. diam. × 0.003-in. thick 2S-H18 aluminum rupture disc. Time between consecutively numbered frames is approximately 2 msec. Frame 1, time 0, the disc is deformed spherically but still intact; frame 2, time 2 msec., a small straight tear is barely visible.



FRAME 3 FRAME 4

Frame 3, time 4 msec., the tear has lengthened and is spreading apart; frame 4, time 6 msec., the spreading process noticeable in frame 3 has resulted in secondary tears roughly normal to the original one, and the spreading continues.



FRAME 7 FRAME 9

Frame 7, time 12 msec., bursting process has exposed entire aperture for pressure relief; frame 9, time 16 msec., spreading of exhaust jet has folded back foil.

This illustration shows the method of taking the photographs 1-4, and 7, 9.

2. Initial Pressure Atmospheric, Impact Loading

After the test disc was bolted in the flange, the quick-opening valve was closed and the upstream line loaded to a predetermined pressure as indicated by the upstream pressure gauge. An air bleed near this gauge facilitated the pressure adjustment. Then the quick-opening valve was opened, which immediately loaded the test disc. If the disc failed, the process was repeated with a lower line pressure until the point of no rupture was found. If the disc did not fail, the process was repeated with a higher line pressure until the point of rupture was found. The rupture pressure recorded was the minimum pressure required for disc failure.

3. Initial Vacuum, Pressure Applied Gradually

After the test disc was bolted in position, the tank was evacuated to 27-29 in. Hg vacuum and held for several minutes. Then atmospheric pressure was admitted and the disc loaded gradually as before to failure. The maximum pressure attained within the test tank was shown by the maximum reading indicator on the compound-pressure gauge. This process was repeated twice more to determine the rupture pressure. On all vacuum tests the iron stopcock was closed during evacuation because the quick-opening valve would not hold vacuum (See Figure 1.).

4. Initial Vacuum, Impact Loading

After the test disc was bolted in the flange, the tank was evacuated as before and then allowed to come to atmospheric pressure before being shock loaded. During the shock tests, there was a drop in line pressure of 6 to 7% when the disc did not fail but merely deformed after the quick-opening valve was opened. To minimize this pressure drop during the vacuum tests, the test tank was brought to atmospheric pressure before being shock loaded. The rupture pressure recorded was the minimum predetermined line pressure required for rupture.

Results and Conclusions

Table 1 is a summary of all experimental work, showing the bursting pressures of aluminum foil rupture discs as functions of diameter, foil thickness, foil temper, initial loading, and rate of application of pressure.

Figure 7, a plot of the bursting pressure of 2S-0 discs (initially at atmospheric pressure and with pressure gradually applied) as functions of disc diameter and thickness, shows a linear relationship between bursting pressure and disc thickness for each of the three diameters tested. Extrapolation of these straight lines to zero bursting pressure gives a thickness of metal of approximately 0.0008 in., which may well be due to the effects of nonhomogeneity and imperfections in the foil.

Tables 2, 3, and 4 summarize the data on the effects of vacuum preloading, of impact loading, and of temper on the bursting characteristics of the rupture discs.

The summary of Table 2 shows that vacuum preloading had essentially no effect on the bursting pressure of the 2S-0 discs that were loaded gradually; those subjected to impact loading also showed no effect of vacuum preloading in eleven out of fourteen tests. In three cases of the impact loading tests the bursting pressure of the 2S-0 discs was decreased from 3 to 4 lb./sq.in. In no case was the bursting pressure of these discs increased by more than 2 lb.

Too few specimens of H 18 discs were available to determine any trend of the effect of vacuum preloading. Where there was an effect with this material, either with gradual or impact loading, its magnitude was much larger than with S-0 alloy. In half of the tests the H-18 bursting pressure was decreased by vacuum preloading.

An examination of Table 3 shows that for all rupture discs tested without vacuum preloading the bursting pressure was essentially the same for both gradual pressure loading and impact pressure loading. Impact loading decreased the bursting pressure by 1 to 2 lb./sq.in. in approximately half of these tests.

For those discs that were preloaded by being subjected to vacuum half of the S-0 specimens showed a decrease of bursting pressure of more than 2 lb./sq.in. for impact loading as compared to gradual loading. The H-18 discs exhibit the same trend, except that again the magnitude of the difference is more pronounced. One of the H-18 discs actually showed a higher bursting pressure under impact loading.

Table 4 shows that, in general, S-0 discs burst at a lower pressure than do S-H18 discs of the same thickness treated identically. The 0.003-in. material did not exhibit this characteristic shown by the 0.001 and 0.005-in. foil, and to a lesser extent by the 0.010-in. foil.

Figures 8*a* and 8*b* are profile photographs of 2S-0 aluminum discs that did not burst under impact loading. These photographs demonstrate that the discs deform spherically. This agrees with Kennard's (*6*) findings that a spherical shape is characteristic of a circular diaphragm loaded uniformly and slowly—slowly as compared to the initial shock-wave loading of an underwater explosion. Hudson's (*4*) conclusion, based on theory that a material that work-hardens should deform spherically, is also dependent upon nonuniform loading, i.e., deformation, starting at the center and progressing outward to the periphery, which is apparently true in this case.

Typical pressure histories of the bursting process are shown in Figures 9*a*, *b*, and *c*. The Rutishauser pressure pickup was installed immediately below the rupture disc (Figures 1 to 4 inclusive), and its trace on the oscilloscope screen was photographed. All these photographs reveal the following sequence of events: (1) a pressure build-up taking place in 20 to 30 msec., (2) an almost instantaneous pressure relief as the disc bursts and freely vents the air, and (3) a period of rapid but relatively minor pressure oscillations as the chamber pressure approaches atmospheric. This sequence of events does not correspond to those for underwater explosions as reported by Hudson (*5*).

Figure 10 shows the bursting process of a rupture disc. These photographs were taken with a 16-mm. Fastax camera on the same horizontal plane as the rupture disc. A mirror was set above the disc and at an angle of approximately 45 degrees to the initially flat disc so that each photograph shows a profile view at the bottom, and a view looking down on the disc at the top. The time between consecutively numbered frames is approximately 2 msec.

Acknowledgments

The equipment was built and the initial test work carried out as part of U. S. Air Force contract 33(600)-17677. Aluminum foil was supplied by the Reynolds Metals Company.

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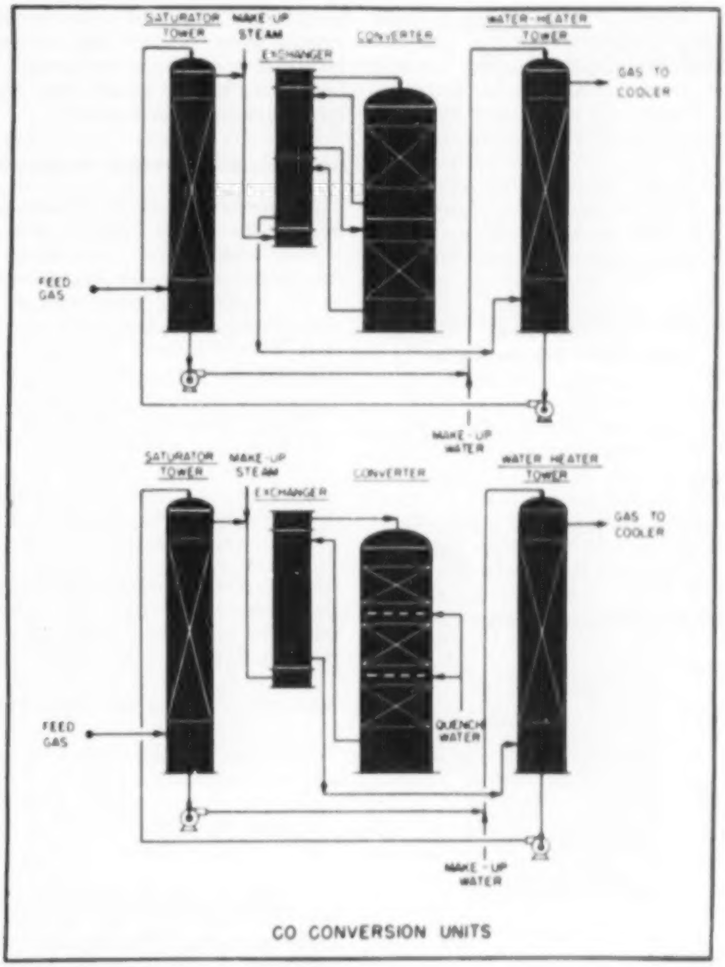
Fig. 1.
CO conversion units.



a method for designing the steam recovery system in carbon monoxide-steam "shift" reaction units

M. C. Sze and J. F. Campagnolo | Hydrocarbon Research, Inc., New York

Raw ammonia synthesis gas often contains a large concentration of carbon monoxide which must be converted with steam in the presence of a catalyst to hydrogen and carbon dioxide. In this conversion or "shift" reaction, the amount of steam used is large. Usually the steam to dry gas ratio in the shift reactor feed is between 2 to 3. Since only a fraction of the steam entering the shift converter is reacted, it becomes economically important to recover the steam in the reactor effluent and minimize the net make-up steam required for the carbon monoxide conversion unit.

When the raw synthesis gas is available to the CO conversion unit at ambient or not excessively high temperatures, steam recovery is usually accomplished by the use of a water heater and a gas saturator tower arranged in typical CO conversion units as shown diagrammatically in Figure 1.

Conventional Method

Raw synthesis gas entering the plant is countercurrently contacted in a tower with hot water. The hot water heats up the gas and saturates it with water vapor to a temperature approaching the entering temperature of the hot water to the humidifier tower. The water leaving the humidifier is cooled, but it is reheated by countercurrent contact with the hot shift converter effluent. In practically all commercial plants using this steam recovery system, the hot reactor effluent entering the water heater is above its saturation or water condensation temperature. Thus theoretically the maximum temperature to which the water can be heated is the "wet-bulb" temperature corresponding to the conditions of the inlet hot gas. This is the temperature at which sensible heat transfer from the gas to the surface of the water is equal to the latent heat requirement of the evaporating water from the surface.

In designing a plant using a steam recovery system of the type just described, one should know the wet-bulb temperature of hot gas to the water heater since this temperature limits the amount of steam which can be recovered and reused for the shift reaction. Thus, with the operating conditions for the converter set, the first thing to determine for the steam recovery system is the wet-bulb temperature of the gas. With this temperature determined, it then becomes possible to set the humidifier overhead temperature approach and design the humidifier tower. Finally the water heater tower can be designed.

Table 1.—Dry Gas Composition

	%
H_2	51.4
N_2	15.9
A	.2
CH_4	.9
CO	2.7
CO_2	28.9
	100.0

π (total press.) = 1 atm.

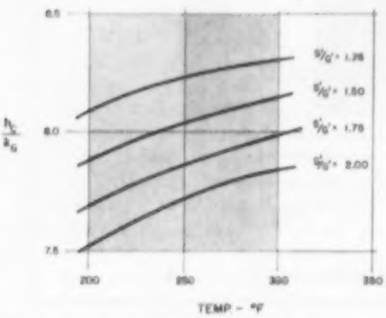


Fig. 2. See Table 1 for gas composition.

Determination of Wet-Bulb Temperature

As previously stated, in the bottom of the water heater tower, the sensible heat transfer from the gas to the surface of the water becomes equal to the latent heat requirement of the evaporating water from the liquid surface. Thus by a simple heat balance, the following equation evolves:

$$A(h_r + h_c)(t_v - t_w) = k_G(y_w - y_v)A\lambda \tag{1}$$

or

$$(1 + h_r/h_c)h_c(t_v - t_w) = k_G(y_w - y_v)\lambda. \tag{2}$$

At the conditions normally prevailing at the bottom of the tower, the radiation effect due to carbon dioxide and steam is small. Rarely is h_r over 0.6 B.t.u./hr. (sq.ft.)(° F.) and h_r/h_c thus can be neglected. Equation (2) then becomes

$$h_c(t_v - t_w) = k_G(y_w - y_v)\lambda \tag{3}$$

or

$$\frac{h_c}{k_G} = \frac{\lambda(p_w - p_v)}{\pi(t_v - t_w)}. \tag{4}$$

In order to solve Equation (4) for the wet-bulb temperature, it is necessary to evaluate h_c/k_G. This fraction can be determined by the use of the analogy between heat transfer and mass transfer (2). Thus,

$$J_D = \frac{k_G}{G_M}\left(\frac{\mu}{\rho D}\right)^{0.56} = J_H = \frac{h_c}{c_p G}\left(\frac{c_p\mu}{k_{Hf}}\right)^{0.56}. \tag{5}$$

The exponent of 0.56 is used in Equation (5) in accordance with the more recent work by Bedingfield and Drew (1). Upon simplification, this equation reduces to the following:

$$\frac{h_c}{k_G} = M_f(c_p)^{0.44}\left(\frac{k_{Hf}}{\rho_D}\right)^{0.56} \tag{6}$$

Figure 2 is a plot of h_c/k_G, evaluated according to Equation (6), for various film temperatures at several steam to dry gas ratios at one atmosphere total pressure for a typical composition of converted ammonia synthesis gas as tabulated (Table 1).

This dry gas composition is used because some commercial operating data for such a gas (as tabulated) are available for checking the calculated wet-bulb temperatures. It may be appropriate to mention here that reasonable variations in the dry gas composition have not been found to affect significantly the factor h_c/k_G when other conditions are held constant.

In a calculation of h_c/k_G from Equation (6) to obtain Figure 2, the constants are evaluated as follows:

M_f is the average molecular weight of the film and is taken analogously for mole fraction midway between y_v and y_w. Since the average molecular weight of the usual dry converted ammonia synthesis gas is fairly close to 18, the molecular weight of steam, the effect of y on M_f is insignificant. Molal specific

Fig. 3. See Table 1 for gas composition.

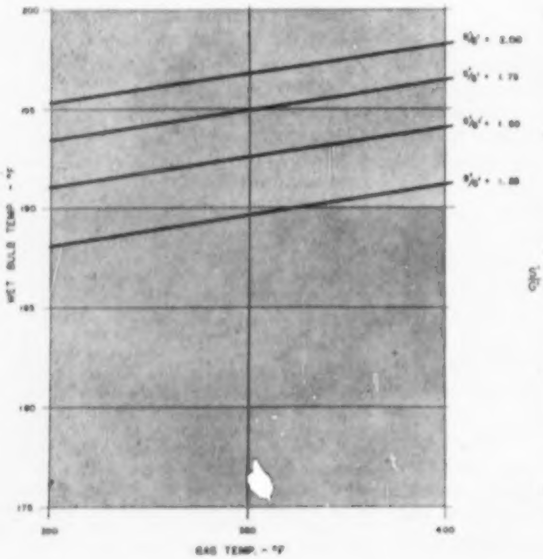
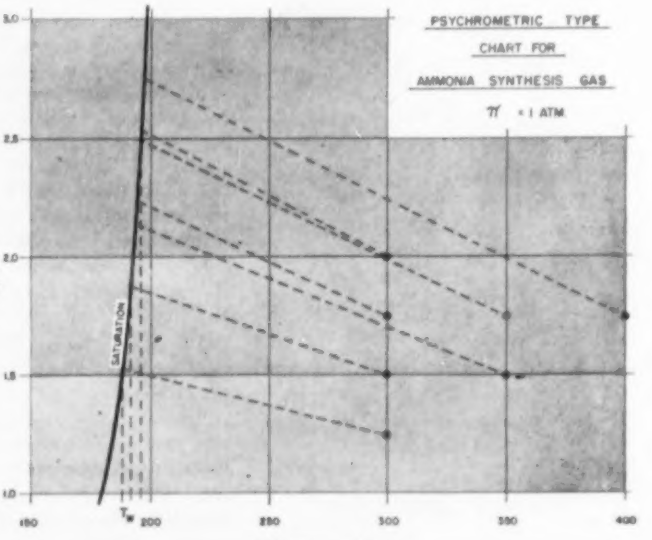


Fig. 4.



heat at constant pressure for the steam and gas mixture is evaluated by averaging the molal specific heat of the various components. The specific heat of steam is taken from the Keenan and Keyes (*4*) steam tables. The molal heat capacity thus obtained is converted to c_p by dividing by the average molecular weight of the steam and gas mixture. Thermal conductivity, k_{Hf}, is evaluated in accordance with the following formula:

$$h_{Hf}\text{-mixture} = \frac{\Sigma k_{Hf} x_i \sqrt[3]{M_i}}{\Sigma x_i \sqrt[3]{M_i}} \qquad (7)$$

For the low pressure case considered for Figure 2, ρ is determined by means of the perfect gas laws. Diffusion coefficient, D, is calculated from the Gilliland equation (3) assuming the dry gas as one component and steam as the other, the molal average molecular volume of the dry gas being used.

Equation (4) can be readily solved by trial and error using the proper value of h_c/k_G from Figure 2. The calculated wet-bulb temperatures for various steam:gas ratios at various gas inlet temperatures for a converted ammonia synthesis gas at a total pressure of one atmosphere are presented (see Figure 3). It can be seen that for wide ranges of inlet gas temperatures and steam:gas ratios the wet-bulb temperature varies only slightly. This becomes more apparent if the results are presented in a form similar to the usual psychrometric chart as in Figure 4. Owing to the steep saturation curve, the wet-bulb temperature or the temperature to which water may be heated varies only slightly at a fixed total pressure for widely varying other conditions. Thus, at a significant increase at steam:gas ratio, the increase in the temperature of the hot water obtained is relatively small. Even though a change of a few degrees in the temperature of the hot water to the saturator tower results in a significant change in the amount of steam recovered, it is, nevertheless, true that as steam:gas ratio is increased the efficiency of steam recovery in such a system decreases. In other words, there is a limit to the maximum steam recovery possible in such a system.

In Table 2 some data taken from commercial operating plants are compared with the calculated wet-bulb temperatures as taken from Figure 3. It can be seen from Table 2 that only at high water circulation rates does the actual hot water temperature leaving the water heater tower become essentially equal to the calculated wet-bulb temperatures. This can be explained that only at a sufficiently high water to gas ratio does the vapor-liquid contacting in the packed towers become very efficient. This is further indicated by the temperature of the gas leaving the saturator tower. As the water circulation rate is increased the temperature approach at the top of the tower narrows and the efficiency of steam recovery improves. This factor is important in the design of the two packed towers.

Pressurized Converters Change Needs

Recently the tendency to design CO conversion units under pressure gained favor. For this reason, the h_c/k_G factors for high pressure operation at 400 lb./sq.in.abs. are calculated and presented in Table 3. It is further surprising to find that within a steam:gas ratio range of 1.25 to 2.00 and a film temperature range of 375 to 450° F., the factor h_c/k_G is practically a constant number.

In an evaluation of the h_c/k_G factor for pressure operation, it was found inadvisable to use the perfect gas laws for estimating the density of the gas-steam mixture. Instead, the following approximate method is believed to be more accurate and thus used. The dry gas volume at the total pressure for one mole is calculated by the use of the compressibility charts and the Kay's rule (*3*) for mixtures. Then the volume of one mole of saturated steam at t_f is taken from the Keenan and Keyes steam tables and converted by a pressure ratio correction factor to the total pressure. For each steam:gas ratio, the approximate steam and gas volumes are added, according to Amagat's law, to give the total volume. This is then used to obtain the vapor density.

By the use of the values of h_c/k_G from Table 3, wet-bulb temperatures for operation at 400 lb./sq.in.abs. are calculated and presented in Figure 5.

Design of Commercial Units

The wet-bulb theory developed above can be directly applied to the design of a commercial unit which must recover

Table 2.—Total Pressure at Water Heater: 1 atm. approx.

	Water flow to saturator (gal./min.)	Gas flow to saturator (std. cu. ft./min.)	Steam gas ratio approx. (mole/mole)	Temp. of gas to water heater (° F.)	Temp. of water leaving heater (wet-bulb) (° F.)	Calc'd wet-bulb temp. from Figure 3 (° F.)	Temp. of gas leaving saturator (° F.)
Plant A	500	6250	1.5	343	189	192	173
Gas composition	500	6900	1.5	362	190.5	193	174
approx. as given	1000	6300	1.5	341	191.5	192	184
in Table 1.	1200	6250	1.5	374	191.5	193	185
	1280	6150	1.5	344	192	192	186
Plant B Gas analysis (dry): %							
H_2 .... 51.5							
N_2 .... 17.8	510	5670	2.0	307	190	195	183
CO 1.7							
CH_4 5							
CO_2 .... 28.5							
100.0							

Table 3.—Total Pressure at Water Heater 400 lb./sq. in. abs.

	%	h_c/k_G for S′/G′ from 1.25-2.00 and t_f from 375-450° F.
Gas composition A (dry):		
H_2	51.4	
N_2	15.9	
A	0.2	
CH_4	0.9	9.5
CO	2.7	
CO_2	28.9	
	100.0	
Gas composition B (dry):		
H_2	55.8	
N_2	0.9	
CH_4	0.3	9.8
CO	1.8	
CO_2	41.2	
	100.0	

steam efficiently so that the shift conversion process can be made economical. The start of any design is to be able to estimate accurately the temperature of water pumped to the top of the saturator tower, as indicated in Figure 1. As has been mentioned previously, the maximum water temperature that can be attained is governed by the wet-bulb temperature of shift converter effluent entering the water heater tower. Figure 3 (for atmospheric pressure) and Figure 5 (for 400 lb./sq.in.abs.) indicate that once the steam:gas ratio is established, the wet-bulb temperature of shift converter gas is also approximately fixed within a range of a few degrees. Naturally, the steam:gas ratio can be set over quite a wide range of values depending on the amount of carbon monoxide present in the synthesis gas and what degree of conversion is desired in the shift converter. However, once these variables have been set according to established operating practice, it is possible then to proceed with the design of the steam recovery system. A plot similar to Figure 3 or Figure 5 is then made and an estimate of the temperature at which shift converter effluent enters the water heater tower establishes the temperature of water pumped to the saturator tower. This temperature may have to be corrected slightly after the first trial calculation. However, ordinarily this will not be necessary because of the insensitivity of wet-bulb temperature to change in gas temperature.

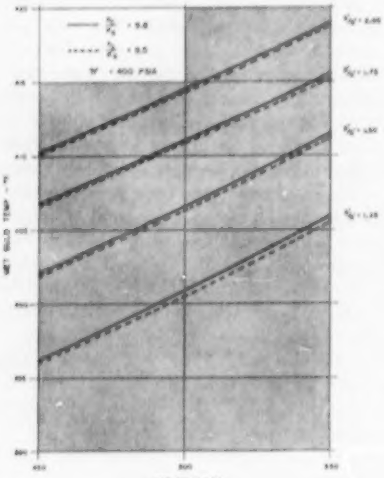


Fig. 5.

The first step in the design of the saturator tower is to plot a saturation curve at the operating pressure of the saturator. If there is to be appreciable pressure drop through the saturator, it would be well to make such allowance. To facilitate construction of the enthalpy curve for saturated gas, a plot is first made of the molal ratio of steam to dry gas in saturated mixture as in Figure 6, which is for a total pressure of 450 lb./sq.in.abs. This ratio can be easily determined as the ratio of partial pressures of steam and dry gas where steam is assumed to exert its full vapor pressure at the temperature. A more accurate plot can be made by correcting the molal ratio in terms of the activity coefficient of steam in the particular gaseous mixture. It was found that this correction was small even at the higher pressures and was not used in the plots. Another useful plot is one for the molal enthalpy of dry gas above a certain datum temperature (Figure 7).

From use of these two curves in conjunction with steam tables, it is possible to construct curves of total enthalpy of dry gas saturated with water vapor over a temperature range that is to be encountered in the saturator. These curves are calculated on the basis of the enthalpy of total mixture per mole of dry gas. It is readily apparent that in all calculations of this nature where dry gas passes through a tower unchanged, it is simpler to work on this basis rather than on total moles of vapor which change in magnitude through the tower.

Curves of this type have been plotted for a low pressure saturator in Figures 8, 9, and 10 and for a high pressure saturator at approximately 450 lb./sq. in.abs. in Figures 11 and 12.

The saturator that is used commercially is a tower that is packed to an appreciable height with 2- or 3-in. Raschig rings manufactured of steel or porcelain. The packing height is necessarily a function of the amount of saturation that is indicated in the process design conditions. Since the primary purpose of the saturator is to effect steam saving, it would hardly pay to use one unless the saturator were designed to recover at least half of the total amount of steam used in any conversion process. Raschig rings are ordinarily used in this service since they are relatively cheap and present reasonably efficient contact surface. However, this does not preclude the use of a more efficient packing material or a bubble tray tower.

In fact, the analysis that follows would be theoretically correct for a bubble tray tower, but can only be an approximation for a packed tower. However, it has been extremely useful in designing towers for saturator service and can be applied also in predicting the performance of the saturator when conditions are changed from design values.

It is assumed in determining the theoretical contacts necessary to perform the required saturation duty that at every point in the tower the gas is saturated with moisture. This necessarily means that the moisture content of dry gas increases as it moves up the tower since its temperature rises in being countercurrently contacted with hot water which is fed at the top of the tower. This assumption is probably correct in the upper part of the tower, but sometimes might not be quite correct in the lower section, primarily in the region just above gas entrance when the entering gas is not saturated. However, it can be seen from the saturation curves that the lower part of the tower is not too important in the analysis

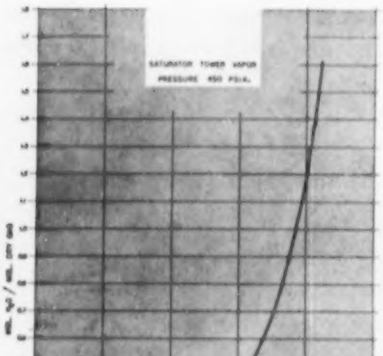


Fig. 6.

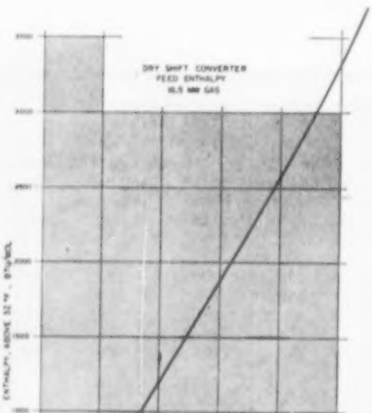


Fig. 7.

since the most critical part of the contacting process is in the upper section of the tower where a pinch is most likely to occur.

Once the assumption has been made that the gas is saturated at its temperature at every point in the tower, it is then an easy matter to establish the water temperatures through the tower. It is necessary to set as design conditions the temperature of gas leaving the top of the tower and a water rate pumped to the top of the tower. It is possible then to proceed down the tower by cutting it by sections at several packing levels. By the assumption of gas temperaure (hence enthalpy) coming into this arbitrary section, an over-all enthalpy and mass balance around this section will permit calculation of the temperature of water leaving. Enough calculations are performed to establish the operating line. In the event that this operating line intersects the equilibrium curve, it is necessary then to go back and establish new outlet conditions so that a pinch will not occur. This can be done by increasing the temperature approach between outlet gas and inlet water, by increasing the water rate, or by some combination of these two variables.

It is seen that the enthalpy difference between gas and water film is a measure of the saturation potential at any point in the tower. In such a system where the water film resistance is negligible and hence bulk and film temperatures are approximately the same, the vertical distance between the operating line and equilibrium curve is the enthalpy driving force. Hence the closer the approach of operating line to equilibrium curve the smaller the potential and hence the more difficult is the process of saturation.

For ease of analysis the saturator is now conceived to contain a definite number of equilibrium contacts which are determined by stepping off vertical and horizontal segments starting from either end of the tower. It is recognized that this method is not strictly theoretically correct and, to be truly correct, a graphical integration must be performed, but in general the results will not be greatly different. This approach has the advantage of being very much faster.

The usefulness of this approach to the design of commercial units is indicated in applying it to operating data which have been obtained from existing saturation units.

Three sets of data are indicated on Figures 8, 9, and 10 for a low pressure saturation operation at approximately 15 lb./sq.in.abs. From a knowledge of the packing height which in this instance was 25 ft. of 3-in. Raschig rings and the number of contacts required, which are stepped off between operating line and equilibrium curve, it is possible to calculate the height equivalent to a contact by dividing one by the other. For the high water rates the height of each contact was approximately 2.3 ft. At a reduced water rate the height of a contact was 3.6 ft. Thus it is evident that to apply an average height of contact in designing a commercial unit it is extremely important that the water rate be high enough so that the packing be completely wetted. It is therefore recommended that for 2- and 3-in. Raschig rings the water rate should be higher than 6000 lb./(hr.)/(sq.ft. of tower section). This recommended rate is only approximate and it is important to make certain that the selected water rate is appreciably lower than the flooding rate.

Figures 11 and 12 are saturation curves at 450 lb./sq.in.abs. The operating lines have been constructed as previously described from a knowledge of the water rate pumped to the top of the tower and from the outlet temperature conditions. The data indicated on these graphs were obtained from two saturator towers, each operating at 450 lb./sq.in.abs. Each tower was packed with 65 ft. of 2-in. × 2-in. Raschig rings. The construction of theoretical contacts for the first unit indicated 21.7 steps when operating under a water rate of 450 gal./min. The second unit which saturated approximately the same quantity of dry gas but was operated at the higher water rate of 560 gal./min. indicated 26.3 theoretical plates. The "H.E.T.P." of the first unit was 3.0 ft. and that of the second, 2.5 ft. However, it is evident that in both cases there is a portion of the tower where the equilibrium curve comes very close to the operating line. Hence, the number of contacts stepped off in this region could easily be in error by several per cent and consequently the agreement in H.E.T.P. values is quite good.

Conclusions

From the data which have been obtained from commercial units the following conclusions can be drawn. The concept of theoretical contacts can be applied to the design of saturator only when the water rate is sufficiently high to wet the packing completely. The construction described here can be used to determine the number of equilibrium

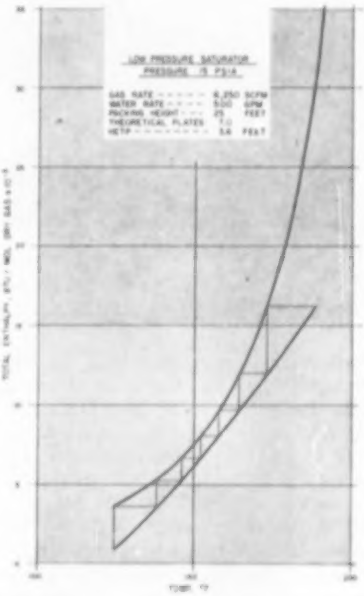


Fig. 10.

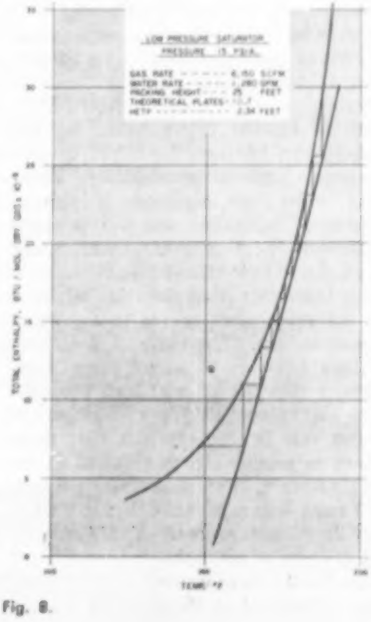


Fig. 8.

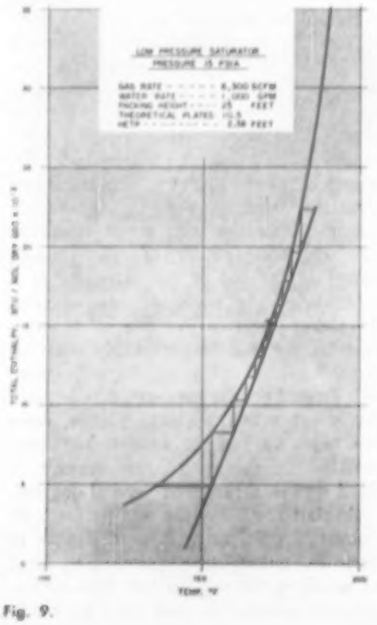


Fig. 9.

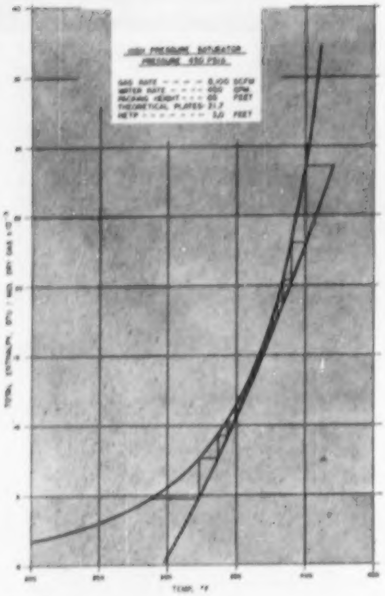


Fig. 11.

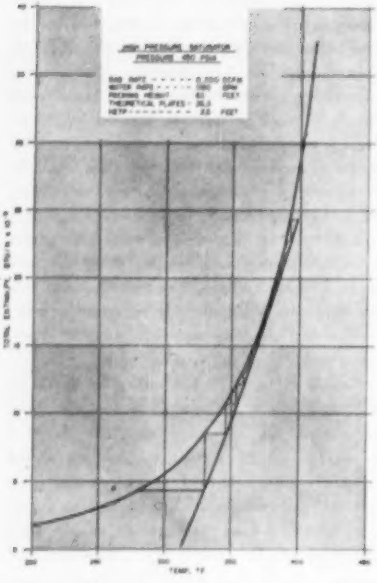


Fig. 12.

contacts by stepping-off plates between the equilibrium curve and the operating line. To determine the height of packing required to perform the desired degree of gas saturation, it is then only necessary to multiply the number of theoretical contacts by the H.E.T.P. of 3.0 ft. for a conservative design but no less than 2.5 ft. for a tight design.

One of the possible uses of the analysis described is in determining new operating conditions on an existing tower after a certain variable in the operation is changed. For instance, it would be possible to estimate the further degree of saturation that would have to be done by a trial-and-error procedure by assuming small temperature approaches at the tower top, calculating operating lines corresponding to these approaches, and drawing in the equilibrium contacts until the number obtained is equal to the number calculated from the original operating conditions.

For a constant inlet water temperature the temperature approach maintained at the top of the saturator is a function of the water circulation rate. As pointed out earlier the inlet water temperature will be reasonably constant regardless of operating variables and will depend on the pressure that is fixed for a saturation system. Hence, once the pressure for the system has been established, the water temperature is fixed within a range of several degrees.

So that the saturator will perform its functions efficiently, it is desirable to keep this temperature approach as small as possible, but not so low that an exorbitant circulation rate must be established which will be evident in high power consumption and very much larger towers. It is noted also, however, that it is just as bad to go to the other extreme and use a very low water rate, as indicated in Figure 10 where the approach is very large, resulting in poor contact because of insufficient packing wetting and low degree of saturation. The recommended range of temperature approach for saturators is in the order of magnitude of 5-15° F. and will be dependent to a greater extent on the total pressure of the system. In general, the lower the pressure the smaller will the temperature approach have to be in order to perform the same degree of gas saturation. In a saturation at atmospheric pressure the temperature approach should be about 5° F. and at 400-450 lb./sq.in.abs. the approach can be from 10-15° F. to perform the same saturation duty. However, under these conditions of identical degree of saturation the low pressure saturator is at a great disadvantage from the standpoint of water circulation. This is evident from the relative slopes of the equilibrium curves in the upper tower section. The slope of the curve at low pressure is about three times greater than the slope at high pressure. The significance of this with respect to water rate is that approximately three times as much water is required at the low pressure. For instance to perform the same degree of saturation about 1.5-2.0 lb. of water are required/std.cu.ft. of dry gas at atmospheric pressure and from 0.5-0.8 lb. of water/std.cu.ft. of dry gas is required at 450 lb./sq.in.abs.

Notation

A = surface area, sq.ft.
c_p = heat capacity at constant pressure, (B.t.u./lb.)(° F.)
D = diffusion coefficient, sq.ft./hr.
G = mass velocity of fluid, (lb.)/(hr.)(sq.ft.)
G' = molar flow of dry gas, (lb. moles)/(hr.)
G_M = molar mass velocity, (lb.moles)/(hr.)(sq.ft.)
h_c = coefficient of heat transfer by convection, (B.t.u.)/(hr.)(sq. ft.)(° F.)
h_r = coefficient of heat transfer by radiation, (B.t.u.)/(hr.)(sq. ft.)(° F.)
H.E.T.P. = height equivalent to a theoretical plate (ft.)
J_h see Equation (5)
J_d see Equation (5)
k_G = mass transfer coefficient, (lb. moles)/(hr.)(sq.ft.)(mole fraction)
k_H = thermal conductivity, (B.t.u.)/(hr.)(sq.ft.)(° F./ft.)
M = molecular weight
p = partial pressure of water, lb./sq.in.abs.
q = heat current density, (B.t.u.)/(hr.)(sq.ft.)
S' = molar flow of steam, (lb. moles)/(hr.)
t = temperature, ° F.
y = mole fraction
π = total pressure, lb./sq.in.abs.
ρ = density, (lb.)/(cu.ft.)
λ = molal latent heat, (B.t.u.)/(lb. mole)
μ = viscosity, lb./(ft.)(hr.)

Subscripts

v, w, f designate values of the quantity in the main gas stream, at the surface of heat transfer or evaporation, and in the "film" respectively, i indicates the components.

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1. Bedingfield, C. H., Jr., and T. B. Drew, *Ind. Eng. Chem.*, **42**, 1164-1173 (1950).
2. Chilton, T. H., and A. P. Colburn, *Ind. Eng. Chem.*, **26**, 1183 (1934).
3. Kay, W., *Ind. Eng. Chem.*, **28**, 1014 (1936).
4. Keenan, J. H., and F. G. Keyes, "Thermodynamic Properties of Steam," John Wiley, New York (1936).

Addenda

In the paper "Generalized Activity Coefficients of Hydrocarbon Mixture Components" (C.E.P., February, 1955, page 95-F), the footnote on page 97-F concerning the large scale, detailed drawings of Figures 1-6 on file with the American Documentation Institute does not give the Document number. This is now known as No. 4484 and the price of microfilm or photoprint is $1.25.

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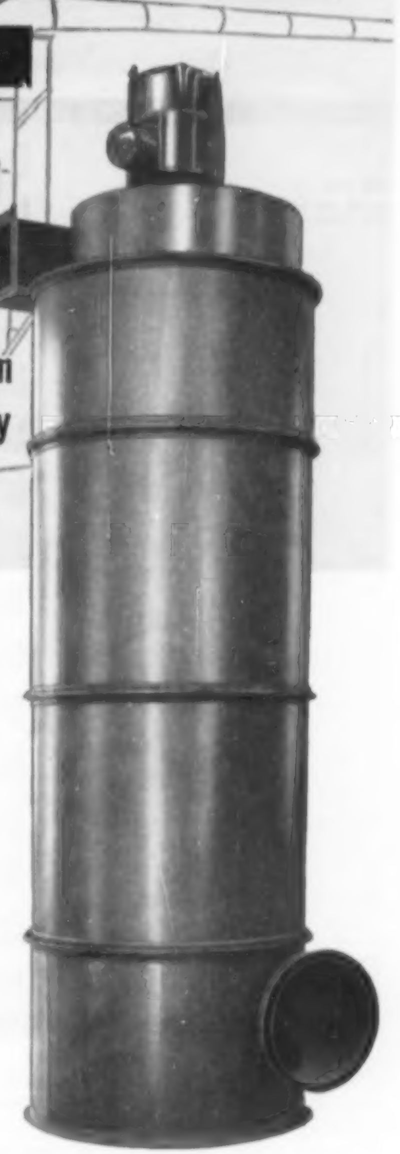

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In operation the Cyclonaire is a wet bed scrubber . . . and the secret of its high efficiency is the bed of Intalox Saddles with which it is packed. Intalox Saddles provide greater randomness of packing and more contact surface area to water and fumes — hence more thorough scrubbing action — than any other industrial tower packing, volume for volume.

The Cyclonaire is constructed of steel in flanged sections which are easily assembled in a few hours — or disassembled and relocated in a comparably short time. Inner surfaces are protected from corrosion by a 3/32″ thick Tygon sheet lining. Outer surfaces are protected with Tygon "ATD" Hot Spray Corrosion-Resistant Paint.

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252-E

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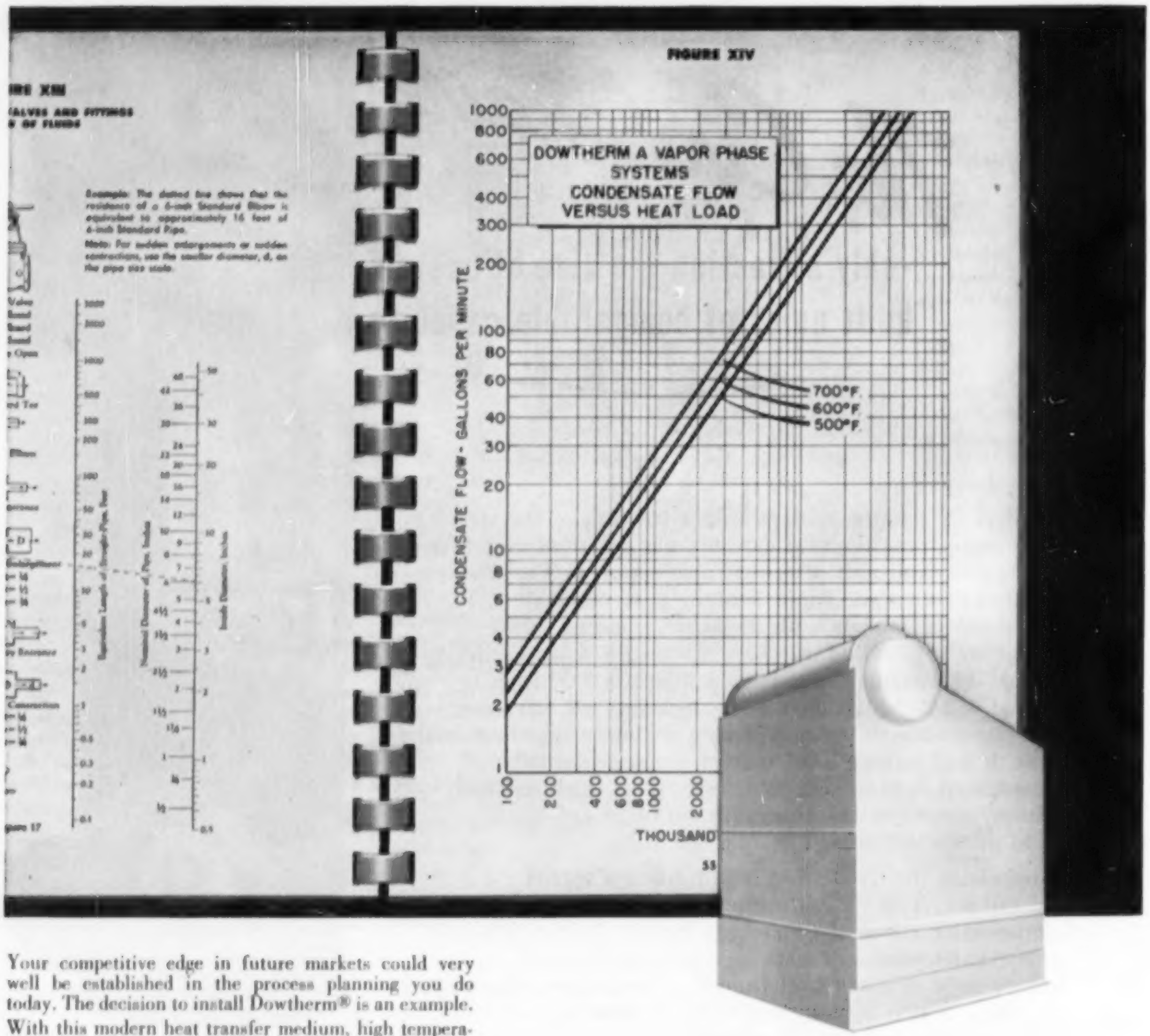

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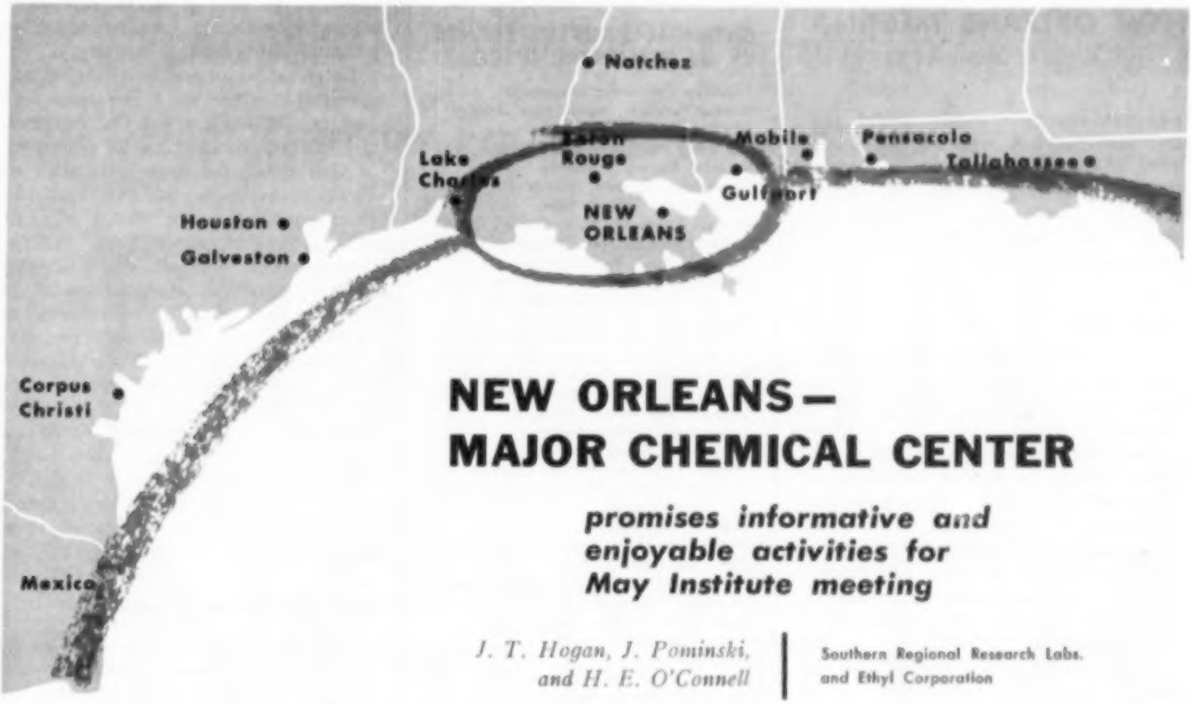

NEW ORLEANS— MAJOR CHEMICAL CENTER

promises informative and enjoyable activities for May Institute meeting

J. T. Hogan, J. Pominski, and H. E. O'Connell

Southern Regional Research Labs. and Ethyl Corporation

In one of he world's major chemical producing areas—the Gulf Coast from the Texas-Mexican border to Florida—Louisiana holds a leading place. The second largest natural gas and sulfur producing state, third largest petroleum producer, fourth largest salt producer, Louisiana centers in turn around the great industrial city of New Orleans.

Main port of the nation after New York, New Orleans is today a major chemical center, eastern focus of the "Golden Gulf" chemical empire that has Houston-Galveston as its Western focus. Reason: abundant raw materials, low cost fuel, cheap, efficient transportation by sea, river and inland waterway, the markets provided by the entire Gulf area and the whole Mississippi waterway system, all but unlimited water, and a climate of a mildness to allow outdoor construction.

The great numbers of resident chemical engineers, the myriad process plants, and an unusual informative technical program, as well as the historic, scenic, and entertainment facilities described in detail last month, all add up to an unmatched opportunity for visitors at A.I.Ch.E.'s National meeting May 6-9.

An "Improve Yourself" Technical Program

A program of more than usual interest has been planned for New Orleans (see pages 52 & 54).

A morning will be devoted to the increasing problems of foreign competition to our chemical manufacturers, process equipment fabricators, and engineering and construction firms. We are living today in a world of ever-widening industrial horizons, but a world in which commercial relations do not yet move freely, and in which there are many problems we must face realistically. More and more knowledge of "foreign affairs" is going to be demanded of both company and engineer if either is going to operate at full efficiency in the future.

A practical "how-to-use" session will be C. F. Bonilla's symposium on liquid metals. You've probably been convinced by now of the value of liquid metals: now you can learn the detailed "know-how" of application at the New Orleans symposium. Sodium will come in for particular attention, including its availability and manufacture, problems of heat transfer, and details of the material transport problem in its use.

This is really going to be a practical "know-how" meeting, with the third "inside information" symposium covering the ever-present problem of engineering writing. Emphasis: how to improve your own writing. It's going to be attacked from four sides at once: what management expects, how management can help you, how you can help yourself without going back to college, and what the editor of technical journals expects.

As if this were not enough to "learn," you and your company or educational institution will have a big stake in the symposium looking into the practical aspects of just how industry and the educators can best provide and use funds from industry in the university. Logically, we know that educational institutions provide industry with its most basic raw material—men. What can industry do to help produce them? How can educators best get the funds they must have to continue doing their job?

The two sessions on fundamental mechanisms in boiling, cavitation and condensation are going to study the subject in detail from both the angle of vapor behavior and measurements of heat transfer in boiling. Leading workers in the field will report on their work, discuss problems, goals and conclusions being reached. In the highly important general sessions, there'll be more on the use of liquid cyclones, the successful use of a photochemical reactor to produce benzene hexachloride, more on multicomponent distillation, and many other highly informative papers.

Meeting Environment—Chemical Boom

Recent announcement of Shell Chemical's new 40 million pounds per year methyl ethyl ketone plant at Norco, to go on stream in 1957, is only one small indication of the chemical boom in New Orleans.

In 1954, $200 million was invested in

(Continued on page 52)

NEW ORLEANS MEETING

(*Continued from page* 51)

new facilities by the oil, natural gas, and petrochemical industries alone. In 1939, 25,000 persons were employed by industry at a cost of some $22 million annually. Today about 54,000 are employed for a total payroll in excess of $175 million per year.

Major Plants

At the New Orleans meeting, plant trips take on a greater importance than usual since so much of the industry in the area is new.

Largest of the recently built plants in New Orleans is Kaiser Aluminum & Chemical's aluminum reduction plant at Chalmette, 6 miles from the French Quarter. Largest plant of its type in the country, it produces 400 million pounds of aluminum annually, using the Soderberg reducion method, cost $165 million to build.

At Luling, 14 miles up-river, Lion Oil has its $31 million installation for the producion of 100,000 tons of nitrogen per year, from 300 to 400 tons of anhydrous ammonia per day. Most of this is processed into other nitrogeneous chemicals such as pelleted ammonium nitrate, nitrogen fertilizer solutions, and aqueous ammonia.

Perhaps the most interesting of the newer plants to the chemical engineer is Cyanamid's giant $67 million Fortier petrochemical plant. Principal products are acrylonitrile, anhydrous ammonia, ammonium sulfate, sulfuric acid, acetylene, and hydrogen cyanide. But most important, at Fortier Cyanamid is using some of the most advanced new techniques of production, control, and analysis in the petrochemical industry.

CHEMICAL PROCESS PLANTS IN MISSISSIPPI DELTA

American Cyanamid, Waggaman
Armour Fertilizer Works, New Orleans
Bay Petroleum, Chalmette
Coastwise Petroleum, Good Hope
Colonial Sugars, Gramercy
Commercial Solvents, Harvey
Cities Service Oil, St. Rose
Davison Chemical (W. R. Grace), Gretna
Delta Petroleum, New Orleans
Dixie Chemical, New Orleans
Freeport Sulphur, Bay St. Elaine, Chacahoula, and Garden Island Bay
General Chemical Div. (Allied), Harvey
Godchaux Sugar, Raceland and Reserve
Henderson Sugar Refinery, New Orleans
International Lubricant, New Orleans
Kaiser Aluminum & Chemical, Chalmette
Lion Oil (Monsanto), Luling
Loisel Sugar, New Orleans
Lone Star Cement, New Orleans
Magnet Cove Barium, New Orleans
Niagara Chemical Div. (Food Machinery), Belle Chasse
Oronite, Oak Point
Pam-Am Southern, Destrehan
Petco, Marrero
Products Research Service, Belle Chasse
Publicker, Westwego
Pure Carbonic, New Orleans
Shell Chemical, Norco
Shell Oil, Norco
Sherwood Refining, Gretna
Stauffer Chemical, Harvey
Southdown Sugars, Houma, Thibodaux, and Vacerie
Swift, Harvey
U. S. Industrial Chemicals, Harvey
Valentine Pulp & Paper, Lockport
Valentine Sugars, Lockport

Large refineries and integrated petrochemical facilities are a prominent feature of the whole area. On the plant trip list are Oronite's works downriver at Oak Point, the large installation of Pan-Am Southern at Destrehan 18 miles up-river where 35,000 bbls. of crude are processed each day, and the Norco refinery of Shell, which is probably the most complete refinery of its size in the world. The refinery at Norco processes 75,000 bbls. per day, supplies raw material to the adjacent Shell Chemical plant for the production of allyl chloride and crude chlorohydrins among other products. Norco is a particularly interesting plant since work is now underway on a 30 million pound per year H_2O_2 unit using a new process, as well as the methyl ethyl ketone plant.

Farm and Mine to Chemicals

Chemical engineers will visit, on the shore of Lake Pontchartrain, a non-industrial installation that is probably one of the most important industrial factors in the region. This is the Southern Regional Research Laboratory of the Dept. of Agriculture, where engineers and scientists are continually working on the industrial chemical possibilities of cotton lint and cottonseed, peanuts, tung, rice, sugar cane, citrus fruits and all the other agricultural products of the South.

(*Continued on page* 58)

NEW ORLEANS MEETING PROGRAM


Beatty


Howard


Katz


Hixson


Olney


Governale


White


Bachelor


Beste


Mellecker

SUNDAY, MAY 6

EFFECTIVE FINANCIAL AID TO THE COLLEGES FROM INDUSTRY—PANEL DISCUSSION, K. O. Beatty, Jr., presiding.

Panel members to lead discussion are:

J. H. Howard, Eastman Kodak Co., Rochester, N. Y.

H. C. Kelly, National Science Foundation, Washington, D. C.

D. L. Katz, U. of Mich., Ann Arbor.

A. N. Hixson, Jr., U. of Penn., Philadelphia.

MONDAY, MAY 7

GENERAL PAPERS, R. V. Bailey, presiding.

Phase Separation and Mass Transfer in a Liquid-Liquid Cyclone, D. J. Simkin & R. B. Olney, Shell Development, Emeryville, Cal.

Phase separation and mass transfer studies made in a 4" dia. cyclone of conventional construction over a wide range of oil/water phase ratios, total flows up to 24 gal./min.

Development of a Two-Stage BHC Photochemical Reactor, L. J. Governale & J. T. Clarke, Ethyl Corp., Baton Rouge.

Highlights of a development program resulting in the commercial application of two photochemical reactor types for benzene hexachloride production.

The Effect of Concentration Level on Mass Transfer Rates, L. E. Westkaemper & R. R. White, Univ. Mich., Ann Arbor.

A differential equation describing mass transfer from values of eddy viscosity and eddy diffusivity is correlated with experimental data from an experiment with CCl_4 being evaporated into a stream of air.

Multicomponent Distillation-Trays At an Operating Reflux, J. B. Bachelor, Parsons Co., L. A.

Having previously developed general equations for the quantity of each component in the feed-zone and product streams, a relaxation solution is now considered for an operating reflux.

IMPROVING COMMUNICATIONS, E. W. Kilgren, presiding.

What Management Expects of Technical Reports, G. W. Beste, Ethyl Corp., Baton Rouge.

A management view of technical reporting from the standpoint of the purposes it is required to serve.

What Editors Expect of Engineering Articles, J. B. Mellecker, "CEP," New York.

Chemical engineering literature can be interesting and factual if the technical writer follows certain specific recommendations.

(*Continued on page* 54)

For Optimum Efficiency at Minimum Cost, Heat Transfer Equipment Needs Kellogg's

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WHEN a process plant's efficiency, and even its economic success, depends on the performance of heat exchangers, this vital equipment becomes more than a "packaged" item or even a matter of following specifications. Optimum performance, at minimum cost to the customer, demands all of the extra know-how, know-when, and know-where that the fabricator can put into the job. It requires, for example, a thorough knowledge of heat transfer, stress analysis, metal fatigue, corrosion control, metallurgy, and welding techniques, plus the inherent ability to apply this knowledge to the specific problem at hand.

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Stearns


Schutte


Binney


Perkins

NEW ORLEANS PROGRAM

(Continued from page 52)

What Engineers Can Do to Improve Their Writing, H. Tichy, Hunter College, New York.

A survey of the advantages and disadvantages of the many aids to better writing, geared to the problems of time, need, and training.

What Management Can Do To Improve Communication, D. Murphy, Service Pipe Line Co., Tulsa, Okla.

Top men in a company set the tone and atmosphere, can do much to increase the quantity and quality of communications.

TUESDAY, MAY 8

FUNDAMENTAL MECHANISMS IN BOILING, CAVITATION AND CONDENSATION, R. R. Hughes, presiding.

The Thermodynamics of Bubbles, J. A. Clark, MIT, Cambridge, Mass.

Outlines those conditions demanded by the laws of thermodynamics for vapor-inside-bubble—surrounding-liquid equilibrium, employs these concepts with a nucleation theory to arrive at an expression relating the nucleating superheat in a pure liquid to other fluid properties.

The Entrapment of Gas in the Spreading of a Liquid Over a Rough Surface, S. G. Bankoff, Rose Poly, Terre Haute, Ind.

The significant parameters for the incomplete displacement of gas from the valley between two parallel ridges by a liquid drop front are found to be the liquid density, surface tension, contact angle, and ridge geometry.

Dynamics of Vapor Bubbles and Boiling Heat Transfer, H. K. Forster & N. Zuber, Univ. of Cal., Los Angeles.

Analytical expressions for bubble radii and growth rates derived by the authors are applied in an analysis of surface boiling at high heat transfer rates.

Heat Conduction in a Moving Medium and Application to Liquid-Vapor Systems, H. K. Forster & N. Zuber, U. of Cal.

A method for the solution of problems of diffusion in a moving medium with given motion of the boundaries, is presented and used to analyze heat transfer between liquid and vapor phase at the phase boundary.

FOREIGN CHEMICAL DEVELOPMENTS AND THEIR EFFECT ON THE U. S. CHEMICAL INDUSTRY, C. W. Humphreys, presiding. (Simultaneous with Boiling Symposium.)

Worldwide Chemical Markets and Their Effect on Our Business, J. C. H. Stearns, Dow Export Co., New York.

The marketing aspects of selling abroad, and of foreign selling here, are considered in light of foreign companies, their advantages, their different practices.

Foreign Chemical Technology, A. H. Schutte, The Lummus Co., New York.

Using specific cases, the effect of foreign processes and technical know-how upon the U. S. chemical industry is discussed.

Commercialization of U. S. Technology Abroad, R. Binney, First National Bank of Boston, Boston, Mass.

Avenues by which the U. S. chemical industry can participate in world-wide chemical markets other than by export.

FUNDAMENTAL MECHANISMS IN BOILING, CAVITATION AND CONDENSATION (Part 2), F. P. Pike, presiding.

Measurements of Bubbles Formed in Boiling Methanol, A. S. Perkins J. W. Westwater, U. of Ill., Urbana.

Results of experimental work using the photographic method to measure bubble sizes and frequencies for methanol boiling at atmospheric pressure outside a ⅜" O.D. steam-heated, horizontal copper tube.

LES MESDAMES

For the ladies a complete program has been planned emphasizing the Vieux Carre, the shops, and all the lingering charm of the historic city of New Orleans.

Sunday, May 6
6:00 P.M.—Cocktail Party.
Monday, May 7
9:00 A.M.—Committee meeting at coffee.
10:00 A.M.—Coffee for all ladies; walking tour of French Quarter.
Tuesday, May 8
10:00 A.M.—Coffee, tour of New Orleans.
2:00 P.M.—Trip on yacht "Good Neighbor."
7:00 P.M.—Mardi Gras dinner party.
Wednesday, May 9
10:00 A.M.—Coffee.
12:00 M.—Lunch at Court of Two Sisters or Patio Royal.

Comparison of Vertical and Horizontal Tubes for Boiling Methanol, C. D. Nelson & J. W. Westwater, U. of Ill., Urbana.

An experiment similar to the above, using methanol under the same conditions, in which results for the horizontal tube were compared to those for a vertical tube.

Transport of Gases Through Liquid-Gas Mixtures, R. V. Bailey & F. M. Taylor, Tulane U., New Orleans. and ORNL, Oak Ridge, Tenn.; P. C. Zmola, Combustion Eng., N. Y.; & R. J. Planchet, Ethyl Corp., Baton Rouge.

Data and analyses are presented for the gas throughput vs. gas holdup in vertical pipes.

Heat Transfer Coefficients for Condensing Organic Vapors of Pure Components and Binary Mixtures, B. S. Pressburg & J. B. Todd, L. S. U., Baton Rouge.

Results of a novel experiment to study various aspects of the Nusselt equation and to extend it to special cases for which existing data are meager.

WEDNESDAY, MAY 9

LIQUID METALS, C. F. Bonilla, presiding.

Manufacture and Availability of the Alkali Metals, M. Sittig, Ethyl Corp., New York.

Present manufacturing processes will be discussed, availability of the metals considered in the light of raw materials, present manufacturing facilities, and future manufacturing expansion.

Control of Oxygen in Sodium Heat Transfer Systems, I. L. Gray, R. L. Neal, B. G. Voorhees, General Electric, Schenectady, N. Y.

The importance of oxygen as an impurity in sodium systems, how contamination can occur, the problem of accurate determination of oxygen and its removal are discussed.

Material Transport in Sodium Systems, F. G. Haag, Knolls Atomic Power Laboratory, General Electric, Schenectady, N. Y.

Results of a three-year investigation into the cause and magnitude of atom redistribution in flowing sodium systems.

Low-Cost Materials for Sodium Heat Transfer System, R. F. Koenig & E. G. Brush, Knolls Atomic Lab, New York.

In the early days of sodium heat transfer systems, emphasis was placed on getting them running regardless of cost. Now cost is becoming an important study.

Static and Dynamic Corrosion, and Mass Transfer in Liquid Metal Systems, L. F. Epstein, Knolls.

Experiments in static and dynamic corrosion are presented in an important and practical paper on liquid metal use.

GENERAL PAPERS, Leon Godchaux, II, presiding.

Thermodynamic Properties of Polar-Nonpolar Mixtures — Methanol-Benzene-Hexane Systems, P. G. McCracken & J. M. Smith, Purdue U., Lafayette, Ind.

Direct enthalpy measurements were carried out and pressure-enthalpy diagrams prepared for methanol-benzene, methanol-n-hexane, and a simple ternary mixture.

Thermal Resistance of an Eddy, L. G. Clark & W. W. Hagerty, U. of Mich., Ann Arbor.

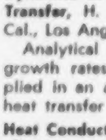
By experimental means a relation is obtained between the thermal resistance of an eddy and its angular momentum.

New Concept in the Correlation of Convective Heat Transfer Data, L. G. Clark, U. of Mich., Ann Arbor.

A method of correlating heat transfer data is proposed differing from the usually accepted method that follows from dimensional analysis.

Fluidization Studies on Non-Uniform Solid Particles, J. K. Jacobs & R. G. Minet, United Engineers & Constructors, Philadelphia.

Fluidizing properties of coal and low temperature char ranging in size from ⅛" to 0 mesh are studied and correlated.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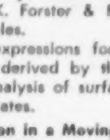
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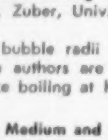
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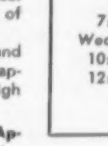
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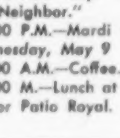
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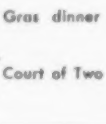
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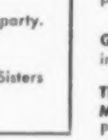
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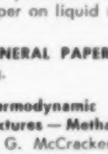
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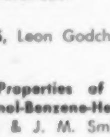
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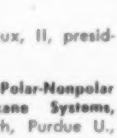
Minet

Small-scale Mixing Rolls Offer Precise Temperature Control

—principle may be adaptable to large-scale rolls

Small-scale mills are widely used to mix test lots of rubber compounds. However, their limited size (6 by 12 in.) makes temperature control difficult, a disadvantage because the properties of the rubber compound are appreciably affected by mixing temperatures. For example, the Mooney viscosity of GR-S compounds increases as the roll surface temperature increases. Also, the tensile stress vs. elongation curves of cured vulcanizates show that stiffness increases and elongation at failure decreases with increasing roll temperature.

Special temperature-controlled steel rolls for mixing of rubber compounds have been developed by the National Bureau of Standards. The rolls use an automatic control system (*1*) based on a thermocouple sensing element to maintain constant roll surface temperature.

The effects of roll temperatures are recognized in the Government specifications for synthetic rubbers and in A.S.T.M. standards, both of which prescribe limits for the temperatures of the mill roll surfaces during mixing. Even though these limits permit a range of 18 or 20° F. in the surface temperature, it is difficult to maintain this temperature control because the rate of heat transfer through the conventional thick-walled roll is too slow.

In recent years it has become increasingly clear that the mixing temperatures of rubber compounds must be controlled if reproducible values for their properties are to be obtained. The Bureau therefore made an intensive study of roll temperature control which resulted in the present roll design.

Small mill rolls are used in pairs; the space between them can be adjusted to control the thickness of the rubber. The rolls turn at different speeds and thus produce a shearing action on the rubber compound. This action is used in introducing into the rubber the various ingredients, such as carbon black and sulfur. Temperature control is especially difficult at the time of the addition of ingredients during mixing.

Most rolls are constructed with a central cavity 1¼ to 2 in. diam. Cooling or heating of the roll is accomplished by spraying water or steam against the walls of the cavity. Since there are two or more inches of steel between the cavity walls and the outer surface of the roll, the rate of heat transfer is too slow to control the temperature within a few degrees, particularly when the heat generated by the rubber compound during mixing varies.

The Bureau investigated a special roll in which the diameter of the cavity was increased to 4 in., leaving only 1 in. of metal in the walls. This roll had an increased rate of heat transfer but did not control temperature as precisely as desired. Another mill roll in which the water or steam travels through spiral cavities near the roll surface had an improved rate of heat transfer. When an automatic controller was used with each roll, the spiral type could control surface temperatures within a range of about 5° F. in mixing soft compounds. However, stiffer compounds requiring more power increased the temperature difference to as much as 30° F. between the sensing thermocouple and the roll surface.

In the roll eventually developed by the Bureau, (see Figure 1) the water or steam flows from one end of the roll to the other through a central cavity and returns through twelve parallel ducts of ⅜ in. diam. The center lines of the ducts are ⅝ in. from the roll surface. A well is provided so that a thermocouple can be placed within ¼ in. of the roll surface. The thermocouple lead wires are connected to slip rings at the end of the roll shaft.

Measurements of temperature changes in the surface of the roll following an abrupt change in coolant temperature show that the rate of heat transfer for the N.B.C. roll (see Figure 2) is greater than for any of the rolls studied. A mill using these rolls and an automatic temperature control system has been in use at the Bureau for about a year. The automatic controller operates from a thermocouple in one roll and regulates the flow of water in a closed circulating system by means of three pneumatic diaphragm valves. Two of the valves admit water or steam to respective heat exchanges, and the third proportions the amount of water admitted to the rolls from each exchanger. This system controls the temperature of the roll containing the thermocouple within 2° F. of the desired temperature during the mixing process. The temperature of the other roll may vary by as much as 7° F. from the control point when there is a rapid change in the amount of power required. However, this variation could be reduced to about 2°, if necessary, by the use of a separate control system for each roll.

Literature Cited

1. Roth, F. L., G. E. Decker, and R. D. Stiehler, *Rubber World*, 132, 483 (1955).

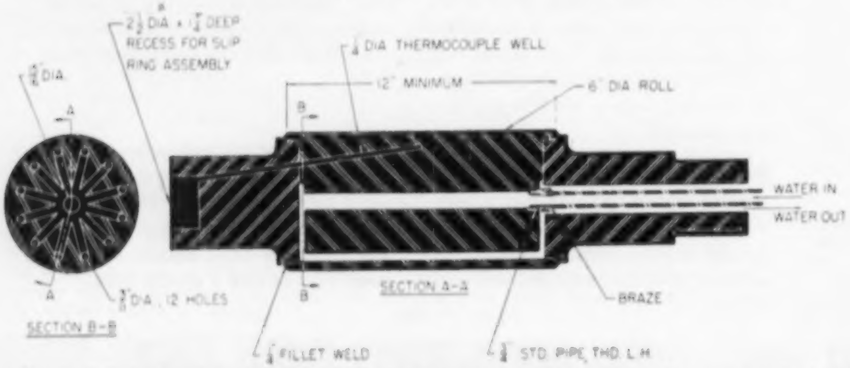

Fig. 1. Roll developed at the National Bureau of Standards for laboratory rubber mill. Circulating coolant enters the central cavity (right), returns through 12 parallel ducts ⅝ in. from the surface. Temperature control system uses a thermocouple sensing element ¼ in. from roll surface, to detect temperature changes. Surface temperatures can be automatically controlled to within 7° F.

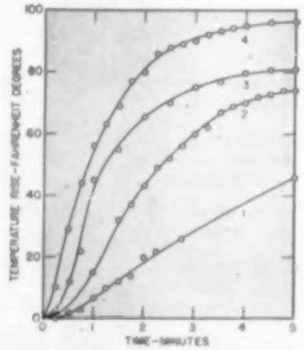

Fig. 2. Illustrates superior heat transfer in mill roll designed at National Bureau of Standards. Curves indicate temperature changes in four different rolls following an increase of 100° F. in temperature of circulating fluid. Curve 1, central-cavity roll with wall thickness of 2 in.; curve 2, central-cavity roll with wall thickness of 1 in.; curve 3, spiral-grooved roll; curve 4, NBS roll.

NEW ORLEANS MEETING

(*Continued from page 52*)

One of the best examples of agriculture becoming chemical industry on the plant trip list is the century-old Godchaux Sugar installation at Reserve. Here the major product is still sugar, 500 million pounds per year, but chemical by-products are growing in importance. At Raceland, Godchaux has a calcium-magnesium aconitate plant, sends molasses to nearby U.S.I. and Publicker plants for production of ethyl alcohol, and supplies bagasse (sugar cane waste) to Celotex's Marrero plant for the production of insulation board. The Celotex plant, also on the trip schedule, is the largest insulation board mill in the world.

LIQUID METALS DISCUSSION SESSION

At the breakfast meeting prior to the Liquids Metals Symposium at Detroit, it was decided that an informal discussion of individual problems and needs in this field might be of value if held May 9 in connection with the New Orleans meeting. It was felt that to achieve an uninhibited and effective discussion, the group would have to be small, limited to those active in the field. Interested participants should write Prof. C. F. Bonilla, Havermeyer Hall, Columbia U., N. Y. 27, N. Y., prior to April 20. If a sufficient number write, an agenda will be compiled and mailed in reply.

Sulfur is one of Louisiana's major minerals. The trip to Freeport Sulphur's Grand Ecaille mines is 65 miles, will be by motor launch down the Mississippi through the picturesque marshlands of southern Louisiana, along winding waterways to Port Sulphur. Once there, the engineer will see Freeport's Frasch process operation over sulfur domes that produce 28% of the *world's* supply of sulfur each year.

Neighbor Red Stick

Only some 85 miles north and still on the river is Baton Rouge, one of the most integrated chemical areas in the country. It is also integrated with big brother New Orleans, is a prime feature on the plant trip schedule.

Here is a large petrochemical center headed by Esso's giant plant and Ethyl's tetraethyl lead plant; a large Solvay works and plants of Consolidated Chemical and General Chemical. Here also is Kaiser's enormous alumina plant which supplies all the raw material for the reduction plant down at Chalmette.

But the most interesting aspect of Baton Rouge's chemical industry is its extreme degree of interdependence. Most plants are, in some way, dependent on the other plants, either for raw materials or markets.

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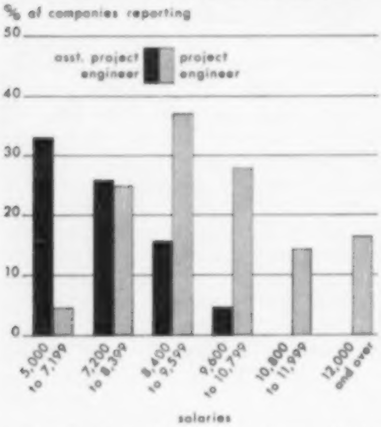

* Larger companies have engineers falling into more than one salary category. See Table 3 on page 62.

The duties, responsibilities, training, salary and other characteristics of the successful project engineer, what industry looks for in a project engineer, are delineated in a recent survey by a member of Union Carbide's project engineering department.

THE PROJECT ENGINEER

—Survey reveals how he's making out

Carl W. Barkow | School of Business Administration, University of Tennessee

Just what is a project engineer's job? What are his characteristics, his rewards, his position in industry?

Just how much does the engineering division, and the project engineer,* participate in the organizing, planning, directing, and controlling of expansion programs and other engineering projects?

To answer these questions, the author undertook an extensive survey, used the questionnaire method directed to major companies with engineering divisions. Survey results are based on 95 completed questionnaires: 62 from chemical companies, 33 from petrochemical and petroleum refining firms.

Place in Corporate Organization

The status of a division in the company often determines the scope and extent of its authority and responsibilities, and of the authority of its members. The manufacturing division, for example, invariably is in general management, i.e. reporting directly to the president. Other levels are: divisional, reporting to a vice-president, and departmental, reporting to a production manager or plant superintendent.

As Table 1 shows, only one-third of the reporting companies give general management status to the engineering division. However, over 75% of the companies give engineering divisional status or better.

Outside Engineering Contractors

A sharp differentiation is shown between the participation of the company engineering division in new construction involving large units and the smaller additions and alterations. Over 50% of the companies hire outside contractors to do all new construction work, while less than 10% use outside contractors for all expansion work. In general it can be said that the large facilities are left primarily to outside engineering firms, additions and alterations are handled by the inside engineering division to a great extent.

In the case of maintenance programs, most companies, regardless of size, do the bulk of the design, procurement and construction with their own engineering division.

* Many companies do not use this term, but use job engineer, plant engineer, etc. For the purpose of this study, all these are called "project engineer."

PROJECT ENGINEER—A PORTRAIT

The survey gives a picture of the typical, or average, project engineer in the chemical and petroleum industries.

He is about 35 years old, although older men are common if they are physically able to handle the job. He has either a chemical or mechanical engineering degree, and was an average student at college. His ten years' experience has probably been in engineering and process design, operations, maintenance, and/or construction. He may have spent some time in research and development, possibly has cost estimation experience, is usually experienced at a drafting board. He has high personal and professional integrity, inspires confidence and respect, and is a tough man when he makes a decision which he does without very much hesitation. He probably has not had formal training in project engineering.

Chances are two to one he has full authority, more or less, over his project, but he will often have to do some selling and persuading within the ranks of his company to do his job the way he wants to. His salary is about $9,600 a year, and is somewhat higher than other engineers of his age and experience. He probably reports to a vice president, undoubtedly has to do a lot of work with outside engineers, and one of his biggest jobs is to keep the plant running.

—*C. W. Barkow*

Duties and Responsibilities

Over 85% of the companies stated that initial policy decisions are made not by the project engineer, the engineering division or the division concerned with the project, but by group action, reflecting again the tendency of present day top management to make major decisions, such as overall scope and manner of a major project, with committees, meetings, conferences, and other non-individual methods.

Once the broad decisions have been made, over 60% of the companies give the project engineer full authority and responsibility to administer the project. However, this situation is shown in the formal organization chart by only a little over 20% of the companies. Apparently, the remaining 40% have either delegated this authority or have simply allowed it to become customary on a more or less unofficial basis.

Despite the preponderance of companies giving "complete" authority, certain facts do emerge to qualify this. Purchasing is generally handled by a separate division. A considerable number of these companies give the project engineer authority only over the design and construction phase of the project, and some only over either design or construction. Not all project engineers are involved in so-called "paper work."

In the companies that give the project engineer authority over only a limited phase—and most do give some authority despite the 30-odd% of "no" answers—

(*Continued on page 62*)

THE PROJECT ENGINEER

(Continued from page 61)

it is clear that the project engineer's job is hampered by the necessity of relying on personal relationships, salesmanship, and the like, to get his job done.

Qualifications and Training

As far as the project engineer's desirable characteristics go, it is interesting to note the emphasis on integrity above technical competence, and the high degree of importance given to the ability to make and stick by decisions.

Over 65% of the companies consider the branch of engineering in which the project engineer had been trained an important item. Of these, some 75% consider a chemical or petroleum engineer highly desirable, and over 60% find a mechanical engineer desirable. (Naturally these figures are not exclusive, being either/or considerations.) These branches of engineering far outdistanced any others. It is interesting to note the very small percentage who consider that the nature of the project makes any difference as far as the type of engineer needed is concerned. Once again, company size appears to be no factor.

It is clear from Table 3 that previous experience is a must for the project engineer, and considerable experience at that. Only some 10% find under five years acceptable experience, some 30% require 10 years or over, with five years the largest single experience group.

Table 2.—Project Responsibilities Given the Project Engineer

Phase of Management Function	Companies Giving: Complete	Companies Giving: Partial
Planning	40	8
Scheduling	43	7
Design Criteria	40	6
Drafting	45	12
Estimating	43	9
Budget Control	43	6
Purchasing	9	..
Expediting	27	1
Construction	44	10
Inspection	40	14
Quality of Work	43	13
Costs	44	9
Acceptance Tests	33	12
Reports	32	9
No Answer	1	5

The favored fields of experience appear to be design and construction, but only slightly more than operating experience. In fact, the most interesting aspect of the desirable fields tabulation is that there is such an even split among 8 fields, with only research and development lagging.

Not shown in the tables is the fact that only some 30% of the companies give the project engineer special training. Of these, 25% give the training before the engineer takes his position. As training methods, coaching and filling the post of assistant seem favored, company courses coming next. In this area size of company appeared to be important, the great majority of companies giving training being in the over 1,000 employees bracket, and nearly half of them in the over 5,000 bracket.

The overall median salary for project engineers, including assistant project engineers, is \$9,120/year, compared to \$9,730/year for all chemical engineers and \$8,780/year for all mechanical engineers in a 1954 survey made by the National Society of Professional Engineers. For full project engineers alone in these 95 companies, the average salary is \$10,020/year.

There seems to be a slight tendency for large companies to pay better, but so slight as to have little meaning in the scope of the survey. On the other hand, men with five years' experience average some \$100/month less than those with 10 years, and the same between 10 and 15.

Table 1.—Position, Duties and Responsibilities of the Project Engineering Department

	% of Companies Reporting
Management Status	
General	34
Divisional	44
Department	20
No Specific	2
Size of Eng'g. Dept.	
Over 300	9
100-300	13
26-99	33
25 and under	43
Construction Work performed by Eng'g. department	
New plants & units	
All	7
75%	6
50%	2
25%	30
None	51
Additions & alterations	
All	25
75%	20
50%	17
25%	26
None	8

	% of Companies Reporting
Policy Decisions	
Initial Planning	
By Group	79
Division Concerned	21
Broad Scope	
By Group	81
Division Concerned	19
Major Policies	
By Group	77
Division Concerned	23
Design Criteria	
By Group	69
Division Concerned	26
Responsibilities & Duties of Project Engineer	
Authority over project	
Full	65
Partial	2
None	33
Design & Const. Phase	
Full	42
Partial	17
Budget Limitations on Project Engineer	
Prior Approval	16
Specific % of Est.	28
Justification R'qd.	30
Govt. Limitations	4

Table 3.—Qualifications of the Project Engineer

	% of Companies Reporting
High scholastic standing	
Important	38
Partly	10
Not Important	47
Age	
No factor	50
Factor	50
30-40	45
Characteristics	
Professional integrity	
Necessary	85
Desirable	5
Personal integrity	
Necessary	88
Desirable	4
Tech. Competence	
Necessary	66
Desirable	26
Respect, cooperation, confidence of others	
Necessary	67
Desirable	25
Decision making ability	
Necessary	77
Desirable	15
Previous Experience	
Not required	8
Required	86
3 years	5
4-5	4
5 years	27
6-10	18
10 years	17
11-15	10

	% of Companies Reporting
Previous experience (cont.)	
Dept. or Field of previous experience	
Design	53
Construction	44
Maintenance	39
Operations	36
Planning	37
Cost Estimation	32
Process Design	28
Drafting	23
Research & Devel.	11
Branch of Engineering	
Chemical	61
Petroleum	13
Mechanical	65
Civil	13
Electrical	11
Industrial	6
Depends on Project	3
Salaries	
Asst. Project Engineer	
\$5000-7199	33
7200-8399	26
8400-9599	16
9600-10,799	4
Project Engineer	
\$5000-7199	4
7200-8399	24
8400-9599	37
9600-10,799	28
10,800-11,999	13
12,000 and over	16

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101BL	101R	102TL	102BL	103R	104L	104R	105R	106TL	106BL
107R	108L	108R	109TR	109BR	110L	111L	111R	112L	113TL
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100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136	137	138	139	140	141	142

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36L	37A	38A	39A	40A	41A	42L	43R	44A	45A	46A
48A	86M	49A	50A	53A	55A	57A	58L	59A	60A	63A
64A	69A	73A	75R	76L	76R	78L	79R	80L	81R	82L
83R	84L	85R	86L	87R	88L	88R	89R	90TL	90BL	91R
92L	93R	96TL	96BL	97R	98TL	98BL	98BR	99R	100L	101TL
101BL	101R	102TL	102BL	103R	104L	104R	105R	106TL	106BL
107R	108L	108R	109TR	109BR	110L	111L	111R	112L	113TL
113RL	113TR	113BR	114L	121TL	121BL	121R	122L	123R	IBC	OBC

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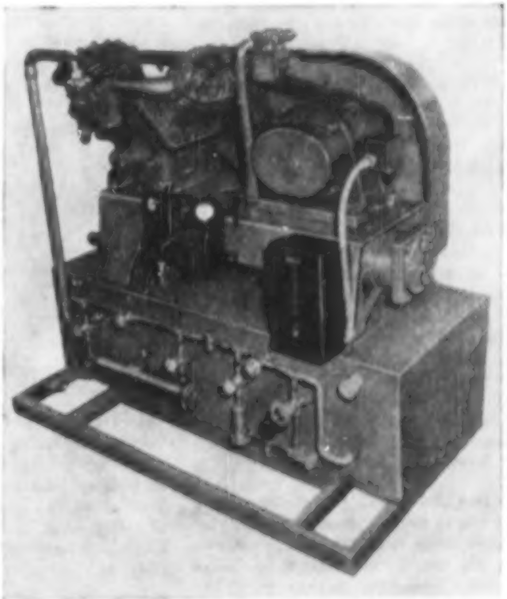


105 PACKAGED LIQUID COOLER unit has been introduced by Doyle & Roth Manufacturing Co., Inc. to meet heavy duty requirements of production of chilled liquids in volume. The package includes a complete refrigeration cycle, compressor, motor & starter, controls, liquid cooler & other accessories, ready for quick installation, immediate operation. Units are available in a range of sizes from 5 to 100 H.P. & for temperatures ranging from 65° F. to —100° F. Literature available on request. Circle number 105 on Data Postcard.

(Continued on page 66)

TURN THIS PAGE TO RIGHT FOR MORE . . .

HOW TO USE THIS POST CARD FOLDER

Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

products-

advertised in this issue

IFC Acetic Anhydride. When you need quick delivery of high-purity acetic anhydride in any quantity call Carbide and Carbon Chemicals Co.

3R Chemical Plant Sifter. Model M Bar-Nun rotary sifter has mechanically controlled full rotary motion. Gives accurate dependable particle size separations in your process. B. F. Gump Co.

4A Valves. Ni-Resist gates look like other valves but they differ in proper design & accurately finished seating. Stay tight even on soap oils & fatty acids. Crane Co.

5A Corrosioneering News. The Pfaudler Co. house organ with information on latest developments in their field.

6A Demisters. One way to insure good performance in Knock-Out drums is to equip them with York demisters. Result is high separation efficiency at low pressure drop. Otto H. York Co., Inc.

8A Gas Reforming Plants. Chemical Construction Corp. designs & constructs heavy chemical plants including those for production of synthesis gas, principally hydrogen, in all parts of the world. Consult them.

9A Valves. Valve clinics to determine needs of industry are regular occasions with Cooper Alloy Corp. Your staff can arrange to meet their engineers in your plant to hold such a clinic, if desired.

10L Corrosion Resistance Materials. If yours is a corrosion problem Atlas Mineral Products Co. offers you a 16-page bulletin on corrosion proof materials of construction to aid in its solution.

11A Filters. Selection of the correct unit for solids-liquid separation is difficult. Eimco Corp. will test samples under your own conditions & recommend the proper unit to employ.

12A Nickel Alloys. Units fabricated from cast stainless steel with high nickel content combat corrosion & erosion. If yours is a metal difficulty consult International Nickel Co., Inc.

13A Jet Propulsion. California Institute of Technology Jet Propulsion Laboratory has job opportunities waiting for you. In a long list of fields.

14L Tower Tests. This is the season best for testing cooling towers. Marley Co. offers a technical bulletin on the subject.

15A Mixers. To avail yourself of reliable fluid mixing in processing consider the various types & sizes of mixers manufactured by Eastern Industries, Inc.

16A Leakproof "Canned" Pump. Now Chempump Corp. has added new features to its leakproof "canned" pump which extends its applications. It has also reduced cost. Simple construction permits mass production techniques.

17A Lithium. If you want to learn how lithium may be successfully employed in your field check the proper category & circle the number above on the card insert. Lithium Corp. of America, Inc.

18L Industrial Strainers. Designed to get liquids trouble-free clean Elliott Co. strainers have proven excellent. Many types with I.D. 1 to 24 in.

19A Nitric Acid Plants. Among the many types of installations designed, constructed & operated by Girdler Co. are nitric acid plants. Process produces 55 to 60% nitric acid with efficient use of catalysts.

20A Unibestos Insulation. No matter how complex your pipeline, Unibestos is easy to install. Standard production sizes. Said to provide greater protection against heat loss even at difficult joints. Union Asbestos & Rubber Co.

21A Process Equipment. Do you want precise construction, unusual materials or special design of your equipment. Whitlock Mfg. Co. puts their engineering, designing, manufacturing & test facilities at your disposal.

22L Industrial Filters. Available in a wide range of sizes & multiple combinations, industrial filters for a variety of uses. R. P. Adams Co., Inc. unique Hi-Flow backwash design permits cleaning without disassembly.

23A Silica Gel. An efficient, economical way to dry natural gas is the use of Davison Chemical Co. silica gel. Has high capacity for moisture even at temperatures 110 to 120° F. Complete technical data available.

24A Stainless Steel Plate. G. O. Carlson, Inc. list things you can do to aid your supplier make his stock of stainless steel plate go a long way. Let these simple rules work for you.

26L Dryers & Heaters. Indirect-fired dryers & heaters from Hardinge Co., Inc. dry without contamination from combustion gases; minimize auxiliary dust collection; collect vapors at high concentration.

27A Heat Exchangers. Precision means profit. Heat exchangers from De Laval Separator Co. said to give perfect control under any operating conditions.

28A Water Conditioning. All the hazards of using low grade water in industry may be controlled by using a system designed for this purpose. Consult the Permutit Co. for details. Literature available.

29A Tubing. Efficient & safe service at extremely high pressures are features of Superior Tube Co. super pressure tubing. Offered in various materials, in sizes 1/8 in. O.D. x 1/16 in. I.D. to 3/4 x 1/16 in.

30L Oil Reclaimer. Some of the features of this unit are continuous, all electric, automatic operation, low operating temperature, vacuum processing. Complete details available in bulletin The Hilliard Corp.

31A Plant Design & Construction. Badger Mfg. Co. are specialists in the design, construction & operation of various types of process plants. Consult them if you are planning expansion.

32A Centrifugal Pumps. If lack of power is limiting centrifuge performance in your plant investigate the Sharples Corp. Nozljector. Drive delivers to 40 h.p. resulting in increased throughput.

33A Dryers. Increased yield with guaranteed product quality are only two features of Proctor & Schwartz, Inc. drying equipment for food & process industries. Complete information available.

34A Stainless Steel. Fabrication of stainless & other alloys is the prime interest of Sun Shipbuilding & Dry Dock Co. Facilities & experience available. All jobs whether large or small invited.

35A Electrodes, Anodes, Molds. Use of Great Lakes Carbon Corp. products assures you of excellent performance because of high degree of integration between laboratory developments & process refinements.

36L Coatings. See the long list of points on which Carboline Co. products score high. For use in comparison of coating systems request the 12 x 18 in. guide form blanks.

DEVELOPMENTS OF THE MONTH *(Cont.)*

106 FLOW DIAGRAMS OF OUTSTANDING PROCESSES IN THE PETROLEUM REFINING INDUSTRY are shown in 69-page brochure by Foster Wheeler Corporation. Clear presentation of flows of charge, intermediates, and products through 41 processes, with operating data whenever available from licensor companies. Among refining methods featured are catalytic cracking, reforming, and polymerization, desulfurization, solvent naphtha fractionation, thermal cracking and reforming, treating and sweetening, and LPG recovery. Each flow diagram is accompanied by explanatory text, and in many cases photographs of existing operating units are shown. With but three exceptions, the diagrams are factual representations of the flows in Foster Wheeler designed units. Circle Number 106 on Data Postcard.

(Continued on page 67)

37A Crystallizers. A first of its kind unit shown. Designed & fabricated of stainless steel alloy it has a quintuple evaporator effect. Specialists at your service to design & engineer equipment for you. Struthers Wells Corp.

38A Flaking. Improving quality & cutting production cost of naphthalene accomplished by use of the F. J. Stokes Machine Co. flaker. A laboratory & advisory service for solution of production problems covered in special bulletin.

39A Methanol Synthesis. Because methanol & ammonia synthesis have much in common long experience in construction & operation of ammonia plants proved invaluable. The Foster Wheeler Corp methanol sequence is illustrated.

40A Autoclave Valve. You can have satisfactory finger-tip operation even at 30,000 lb./sq.in. using the Autoclave Engineers, Inc. valve. Special packing for temperatures to 1,000° F.

41A Fat Splitter. For economically splitting high quality fatty acids in small quantities, Blaw-Knox Co. offers a simply operated unit. An effective adjunct to larger units to avoid interruption while processing small lots.

42L Packing. Teflon Chemiseal packing from U. S. Gasket Belmont Packing are available for every process need. V-rings are all Teflon, low-friction, all-chemical resistant. Bell-Vee is general purpose packing.

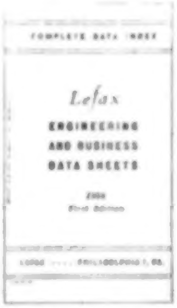
43R Booster Pumps. Called Verti-Line these units are products of Layne & Bowler Pump Co. & join their years of experience in manufacture of pumps with know-how of General Electric in production of submersible booster pumps.

44A Filtration System. Three models of water filters installed in system illustrated cover filter area of 1,200 sq.ft. Efficiently handle 5,000,000 gal. of water per day. Other models available. Sparkler Mfg. Co.

45A Mist Eliminators. You can stop costly liquid loss in process vessels with Schuyler-knit mist eliminators. Fabricated from wire mesh for use in chemical & petroleum industries. Immediate delivery on variety of shapes. Schuyler Mfg. Corp.

46A Valves. Solid porcelain valves made from Lapp Insulator Co., Inc. special porcelain. Insure purity of product, are non-porous, & have high mechanical strength. Bulletin gives details.

DEVELOPMENTS of the month (Cont.)



107 LEFAX TECHNICAL DATA CATALOG for 1956. Newly revised catalog of pocket sized technical data books is announced by Lefax publishers of Philadelphia. These handy reference books cover every branch of engineering. Each book contains approximately 140 pages of data including latest advances.

108 INDUSTRIAL WASTE TREATMENT DATA is presented in a paper available from Milton Roy Co. of Philadelphia. Several practical systems for process & waste water treatment utilizing controlled volume pumps to meter chemicals & additives are described.

(Cont. on page 68)

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

Postage Will Be Paid by Addressee

BUSINESS REPLY CARD
First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

No Postage Stamp Necessary If Mailed in the United States

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

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CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

products-(Cont.)

advertised in this issue

86M—A Mixers, Rotameters, Flow Indicators. Send for a condensed bulletin offered by Schutte and Koerting & get acquainted with all types of SK jet apparatus.

48A String Filter. For use in jobs ranging from thick porous cake to thin sticky slimes. This unit is only one of many types of Filtration Engineers, Inc. continuous rotary vacuum filters.

49A Fume Washer. A complete package-type fume washer in standard sizes & only a fraction of the size of custom units is offered by U. S. Stoneware Co. Capacities from 750 to 6,500 cu.ft./min.

50A Dowtherm. A modern heat transfer medium for use at high temperatures & low pressures. An accepted tool for the process engineer. Dow Chemical Co.

53A Heat Exchangers. M. W. Kellogg Co. offers built-in engineering in their heat exchangers. Combines all the elements for optimum performance at minimum cost.

55A Vertical Turbine Pumps. If your need is to handle large volumes of water at medium to high operating heads, Ingersoll-Rand Co. vertical turbine pumps offer advantages. In single or multi-stage units, capacities 60 to 14,000 gal./min. at heads of 10 to 100 ft./stage.

57A Uniclosed Motor. From U. S. Electrical Motors Inc. the revolutionary type H unit. Features include asbestos insulation, Lubriflush bearing construction, Ventrifoil baffles.

58L Heat Exchangers. Standard stainless steel & designed to meet requirements of chemical & petrochemical industries, heat exchangers from Doyle & Roth Mfg. Co., Inc. Literature & information offered.

59A Filters. Staynew liquid filters are effective with a long list of chemicals. Also filters of every type for any requirement. Dollinger Corp. Bulletin gives engineering & performance data.

60A Karbate Process Equipment. Using equipment made from Karbate impervious graphite guarantees corrosion resistance, rugged design, high thermal conductivity. Technical advisory service. National Carbon Co.

63A Stainless Steel Tubing. Eliminate downtime & labor cost by replacing worn tubing with tubing of stainless steel. Consult Mr. Tubes at Babcock & Wilcox Co.

64A Granular Products. Allis-Chalmers offers a complete process system for converting fine particles into a granular product that will meet consumer demand. Starts with —30 mesh chemical salt.

69A Spray Dryers. The complete range of high tonnage spray dryers manufactured by Bowen Engineering, Inc. described in one interesting bulletin. Ask for a copy.

73A Process Filters. A line of process filters from Process Filters, Inc. is illustrated. Information on these efficient, trouble-free, high production units is offered.

75R Process Design & Engineering. Vitro Corporation of America is prepared to design, engineer, & construct the best in technical facilities whether nuclear or non-nuclear. Information available.

76L Laboratory Ware. Made of Vitreosil fused quartz these laboratory units offer chemical purity, high resistance to heat & unusual electrical resistivity. Thermal American Fused Quartz Co., Inc.

76R Dust Collectors. No matter where you wish to install them these dust collectors occupy unproductive space. Save in many other ways. Claude B. Schneible Co.

78L Liquid Oxygen Pump. At 297.4° F. this vertical top-suction pump functions well overcoming usual difficulties encountered at boiling point of liquid oxygen. If your problem involves pumping a liquefied gas at extreme low temperature Lawrence Pumps Inc. will be glad to make recommendations.

79R Heat Transfer & Process Units. Those shown are only a few of many designed & fabricated by Manning & Lewis Engineering Co. Experience in working with all ferrous & non-ferrous metals.

80L Heat Exchangers. Steel & alloy plate fabrication of heat exchangers is the business of Downingtown Iron Works, Inc. Design recommendations available.

81R Centrifuges. For handling liquid-solid clarification; liquid-liquid-solid separation; liquid-liquid counter-current solvent extraction & concentration of solid investigate the Westfalia units available from Centrico Inc.

82L Graphite Process Equipment. Various types of heat exchangers, coolers, pumps & rupture disks made from Impervite impervious graphite are products of Falls Industries Inc. Material provides excellent thermal conductivity.

83R Mix-Muller. Simpson Mix-Muller Div. of National Engineering Co. offers a Handbook on Mulling available to all who mix dry or semi solid materials.

84L Heat Exchangers. Down time & tube fouling are eliminated when you use Paracoil self-cleaning heat exchangers. Contain a movable baffle assembly which serves as a scraper mechanism. Davis Engineering Corp.

85R Ball Joints & Steel Pipe. Recommended by major users of chemicals Barco Mfg. Co. flexible ball joints & steel pipe. Inset shows 4-joint line from pump barge to shore. Line may move 30 feet up & down.

86L Castings. In addition to their regular line Duraloy Co. offers static sand, centrifugal & shell molded castings. Ask them for recommendations if you have a casting problem.

87R Extruder. Designed to extrude a range of materials economically extruder handles materials previously impossible to process by this method. Any size or capacity. National Drying Machinery Co.

88L Worm Gear Reducers. Single & double reductions available in horizontal right angle type with output shaft above or below worm shaft. Reduction ratios $7\frac{1}{6}$ to 60:1; h.p. .081 to 262.89. Philadelphia Gear Works.

88R Gage Illuminators Approved by Underwriters' Laboratory, explosion-proof gage illuminators from Jerguson Gage & Valve Co. employ principle of solid wedge lighting, eliminate glare.

89R Hydrocarbon Resins. If you compound rubber, investigate Panarez resins. Available in any color from Barrett No. 1 to 18, softening point from 40° to 300° F. Supplied in flaked or solid form. Pan American Chemicals Corp.

90TL Aluminum Grating Walkaway & Handrailing. Illustrated is a typical installation used in the petroleum industry. Also manufacture various types of process equipment. Washington Aluminum Co., Inc.

90BL PVC Piping. Unplasticized PVC piping with injection molded fittings lasts indefinitely. Handles many acids. Pressure ranges to 100 lb./sq.in. Booklet describes properties. Tube Turns Plastics, Inc.

91R Grinders. Schutz-O'Neill Co. announce availability of their pilot plant for making test grind of your sample. Processed material with report & recommendations will be returned for your consideration.

92L Automatic Process Control. This is the title of a new publication from John Wiley & Sons, Inc. Said to be a basic systematic approach to analysis & design of control systems.

(Continued on page 70)

DEVELOPMENTS OF THE MONTH (Cont.)

109 STEAM-JET EJECTOR APPLICATIONS HANDBOOK of 60 pages available from Worthington Corp. describes selection of single and two-stage stock ejectors for general vacuum service. Included are application ranges and selection tables on single and two-stage stock ejectors, dimensional and installation data, and information on sections and parts lists. An engineering reference section details ejector terminology and the principles and procedures of ejector selection and application. Appendix provides formulas, air-water vapor saturation curves, and tables on air density, molecular weight of common gases, and temperature and unit conversions. Circle Number 109 on Data Postcard.

(Continued on page 71)

products- *(Cont.)*

advertised in this issue

93R Vaporizer. A better approach to vaporizing problems is said to be accomplished by use of Richard M. Armstrong Co. equipment. Strong mechanical construction. Tube ends welded for maximum strength.

96TL Thermocouple Assemblies. Units said to be leakproof to pressures to 80,000 lb./sq.in. & temperatures to 1,000° F. are products of American Instrument Co., Inc. Other superpressure products available.

96BL Tanks. Fabricated of welded steel & all other metals, tanks of every type are the product of Posey Iron Works, Inc. Custom built to your specifications plus budget & delivery requirements.

97R Filters. Announced by Industrial Filter & Pump Mfg. Co. the self-cleaning Hydra-Shoc filter. Tubular unit creates own air pressure. Minimum space requirement. Eliminates water for cleaning & back flow pumps.

98TL Tubing. Precision bore tubing in various shapes & sizes available from Wilmad Glass Co., Inc. Made of Pyrex or Vycor glass & most electronic glasses.

98L Rotary Pumps. Some features of the Eco Engineering Co. All-Chem rotary pump are capacities 1 to 10 gal./min.; pressures to 150 lb./sq.in.; stainless steel housings; choice of impellers; available from stock for direct motor.

98BR Rotameters. Called Safeguard, unit is said to offer features listed. Other information available. Schutte and Koerting.

99R Chlorination. Formation of slime on the condenser & heat exchanger result in heat losses. Can be eliminated by chlorination of cooling water. Wallace & Tiernan Inc. invite your inquiries concerning their several systems.

100BL Conveyor. An enclosed conveyor for a variety of chemicals is the product of Buhler Bros., Inc. Advantages of its use are dustfree, sanitary operation, high capacity, conveys hot materials at temperatures to 900° F.

101TL Ejectors. Ingersoll-Rand steam jet ejectors save your steam. Single one piece nozzle prevents internal leakage. No matter what your application there is a suitable unit.

101BL Heat Exchangers. One of the many products of the Rempe Co., a special deep tank heating coil is illustrated. Stainless steel fabrication, & 25 ft. long overall. Units available in other materials.

101R Liquid Level Control. Called Magnetrol unit is as simple & dependable as pull of a magnet. No wearing parts to get out of order. Control changes from .0025 in. to 150 ft. with single or multi-stage switching. Magnetrol, Inc.

102TL Mills. Bauer Bros. Co. fabricators of mills, crushers, grinders, etc., for reduction of all kinds of materials invite you to present your problem to their engineers for solution.

102BL Filter. An enclosed horizontal plate filter said to be leakproof & vaporproof, for batch or continuous operation & easy to clean manufactured by T. Shriver & Co., Inc. Cake remains in place even when run is interrupted.

103R Tower Packing. Called Tellerettes this new polyethylene tower packing said to provide remarkable increase in efficiency & capacity. Interlocking effect of packing provides holdup points for liquid films. Maurice A. Knight.

104L Jet Mixer. Hermes Machine Co. jet mixer offers complete circulation. No vortex, all material uniformly treated. Material continually recirculated.

104R Process Vessels. If you are looking for pots for your process system facts are available in Chemical Engineering Catalog which will enable you to explore the field. Published by Reinhold Publishing Corp.

105R Tantalum. Equipment cost is measured by cost/pound or ton of product/year. Tantalum, immune to acid attack is an attractive material of construction. Information available from Fansteel Metallurgical Corp.

106TL Laminates. Glass reinforced polyester, epoxy, phenolic laminates, tanks, ducts, pipes & parts afford corrosion resistance & electrical insulation. Consult Carl N. Beetle Plastics Corp.

106BL Spray Nozzles. Binks Mfg. Co. complete line of industrial spray nozzles & cooling towers are shown in their new comprehensive catalog. Available on request.

107R Pebble Mills. These & other grinding equipment available from Paul O. Abbé. A 48-page catalog describes & illustrates units in their line.

108L Defoamers. Use of silicone defoamers increases your profits. Two types. One for process industries including textile, paper, rubber, etc. The other for food processing. Dow Corning Corp.

108R Ion Exchange. If your process requires chemically-pure water you can obtain it economically by deionization. Investigate specially designed equipment available from Illinois Water Treatment Co.

109TR Pilot Plants & Process Equipment. Design & manufacture of these units has been the work of Artisan Metal Products, Inc. for many years. If you have a problem notify them & an engineer will call.

109BR Sprocket Rim. Any valve is readily accessible from the floor using this newly redesigned adjustable sprocket rim. Affords greater strength & more solid assembly. Babbitt Steam Specialty Co.

110L Pressure Gauge. Ace Glass Inc. use Trubore tubing in their McLeod gauge. Assures accuracy & interchangeability within each pressure range. Holds at any position to which it is rotated.

111L Pumps. A progress report on pumping for chemical engineers has been prepared by The Aldrich Pump Co. Other information available on pumps suitable for your need.

111R Plastic Stacks & Tanks. Manufactured by American Agile Corp. plastic ductwork. Said to have longer service life than equipment made from other materials.

112L Radiameter. A survey meter for use in radiation surveys from Curtiss-Wright Corp. Two ranges with accessories to multiply or divide both ranges by 10.

113TL Pumps. Steam jacketed herringbone gear pumps handle viscous materials of many types. Constructed by Schutte and Koerting. Other process units available. Bulletin describes pump line.

113BL Spray Nozzle. For effective spraying you require exact spray pattern, impact, spray angle & capacity. Spraying Systems Co. nozzles will meet these requirements. Catalog includes performance data.

113TR Laboratory Glassware. Built-in accuracy & uniformity are features of Doerr Glass Co. laboratory ware. Graduations carefully calibrated. Pigment in Diamond D blue line is heat-fused into graduations.

113BR Bin Level Indicator. The Bin-Dicator Co. Bin-Flo aerating unit provides steady flow of materials. Uses small amount of low-pressure air. Bin-Dicator bin level indicator for all bulk materials.

114L Pressure Fuses. Available for immediate delivery high pressure, ermeto & pipe connections. Accuracy ±3%. Sizes ¼ to 3 in. Pressures 100 to 40,000 lb./sq.in. Constructed from 316 stainless steel. Pressure Products Industries, Inc.

121TL Ejectors, Condensers, Vacuum Equipment. Constructed from variety of materials units have corrosion resistant parts interchangeable with standard parts. Jet-Vac Corp.

121BL Hydraulic Presses. Two new HPM 1,200-ton presses, with 15 openings, size 100 x 120 in., fully automatic, installed on foundation. Located at Ford Motor Co. & available for resale. United Paper Machinery Corp.

121R Wire Screen. Made from all corrosion-resistant metals & alloys these screens designed for longer life & better service. Woven to individual specifications. Also available filter segments & strainer elements. Cleveland Wire Cloth & Mfg. Co.

122L Insulated Wire. Whatever your wire requirements Claud S. Gordon Co. has a type suitable for your use. Special insulation in long or short runs available.

123R Jet Units. From Croll-Reynolds Co., Inc. a variety of jet units are listed. Also Evactor steam jet air pumps, boosters & thermocompressors, Chill-Vactor refrigerating equipment, etc.

IBC Pumps. Controlled volume pumps & complete chemical feed systems from Milton Roy Co. guarantee dependability. Practical solutions to your metering problems may be found in one of the bulletins offered.

OBC Mixers. Every Lightnin mixer carries a guarantee to do the recommended job. Many helpful facts on mixing may be obtained from literature offered by Mixing Equipment Co., Inc.

1 Chemicals. Characteristics & uses of chemicals & other products derived from tin, antimony & zirconium, are considered in a 6-page 2-color bulletin from Metal & Thermit Corp. Product groups include inorganic & organic tin chemicals, organotin stabilizers, stannous soaps, antimony chemicals, zirconium products.

2 Mechanical Tubing. Product engineers requiring knowledge of alloy mechanical tubing will be interested in a Babcock & Wilcox Co. bulletin on the subject. States advantages to be gained in utilization of this tubing.

3 Steam Jet Vacuum Pumps. New bulletin describes two-stage vacuum pumps both condensing & non-condensing. Covers applications, size & dimension tables & performance characteristics. Color illustrations of operating flows are included. Schutte and Koerting Co.

4 Corrosion Guide. 12-page Corrosion Guide lists classifications for fourteen alloys & materials for wide range of corrosive agents & conditions. Makes available to users handy & comprehensive reference guide. Misco Fabricators Inc.

5 Evaporators. Evaporation equipment covering range from volatile solutions to powder described in new bulletin from Rodney Hunt Machine Co. Photos, text & drawings explain operating principles & specifications of Turba-Film & Turba-Film floating blade evaporators, & Rodney Hunt-Luwa spray dryer.

6 Fluorocarbon Molded Products. Expansion bellows & pipe elbows made from chemically inert fluorocarbon resins now offered by Resistoflex Corp. Recommended for applications involving acids, caustics, hot lacquers, & synthetic oils under extreme temperature conditions.

7 Pumps. Released by Allis-Chalmers Mfg. Co. bulletin on ACAP pumps for handling solids in suspension under variable capacity & head conditions. Units may be manually or automatically controlled. Cutaway drawings & dimensional specifications included.

8 Packaged Plants. Conversion of anhydrous ammonia to aqueous ammonia; & plant layout & equipment for production of ammonia phosphate covered in bulletin on packaged plants from J. C. Carlile Corp.

9 Pump Impellers. Recent findings on the physical & chemical characteristics of non-metallic impellers for displacement pumps in 4-page illustrated folder "Non-Metallics for Impeller Pump Use" from Eco Engineering Co. Synthetic elastomers, fluorocarbons & resinous laminates surveyed.

10 Process Pumps. Available from Ingersoll-Rand a 20-page 2-color bulletin on process pumps. Fully describes vertically split, single- & two-stage type pumps. Contains cross sectional & installation views, dimension tables, design features. Capacities to 3,200 gal./min., heads 925 ft., at temperatures to 800° F.

11 Steam-Jet Ejector Applications. A 59-page binder insert handbook on the subject of Steam-Jet Ejector Applications offered by Worthington Corp. Contents include application ranges & selection tables on single & two-stage stock units, dimensional & installation data plus sections & parts lists, & a reference section. Appendix provides formulas, curves & tables on air density & other features.

12 Infrared Analyzer. Announcement of a dual beam, non-dispersive infrared analyzer for use in continuous measurement of CO concentration in hydrogen-nitrogen mixtures to prevent catalyst poisoning in reactors. From Applied Physics Corp. Automatically restandardizes against a reference gas every thirty minutes.

√ **CHECK** *your Data Service requests on the handy postcard on page 65 to*

▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

14 Flow Regulator. Improvement of product quality & increased filter efficiency of up to 33% are claimed for an automatic flow regulator from W. A. Kates Co. Said to maintain constant flow through the filter at its rated gal./min. during entire filtration cycle. Has a 5 to 1 adjustable range & is designed for handling suspended solids without clogging or inaccuracy.

15 Venturi Tubes & Nozzles. Engineers will be interested in a comprehensive & well-documented bulletin from Simplex Valve & Meter Co. Deals with measurement of liquid flow, variations in design occasioned by effect of temperature, high line pressures handling corrosive fluids during measurement of fluid flow. Simplex type TG Venturi tubes & nozzles & applications to process industries considered.

16 Selection Guide. For those in need of a guide for selecting an engineering firm Teller Co. has published a booklet for use by top management. Differentiates between the engineering installation firm, project engineering firm, & engineering design firm. Sketches criteria for determining adequacy of present staff to do job in hand & outlines guide posts for selection of outside engineering firm.

17 Steam Generators. New binder insert catalog on steam generators & custom metal fabrication contains fourteen pages of engineering drawings of boilers of capacities producing to 500,000 lb./hr. of steam on standard fuels. Also shown are engineered units for waste heat applications & others designed to utilize refuse for fuels. Wickes Boiler Co.

18 Seamless Welding Fittings. A 6-page folder from Babcock & Wilcox furnishes in concise form types & size ranges of various welding fittings & flanges available, & fabricated from alloy, carbon or stainless steel.

19 Hydraulic Tube Fittings. An illustrated catalog covering hydraulic (straight thread) tube fittings provides full dimensional information on complete line of Tube & Hose Fittings Div., Parker Appliance Co.

20 Armored Purge Meter. Fischer & Porter Co. have developed an armored purge meter featuring all-metal construction—1,500 lb./sq.in. pressure rating which provides safe, inexpensive metering of any purge fluid. Uses a magnet & follower to indicate flow rate & is suitable for any chemical or processing installation. Two sizes. Bulletin.

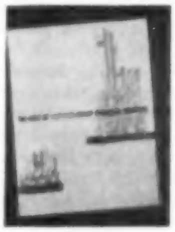
21 Nuclear Technology. A 4-page folder from Advanced Scientific Techniques Research Associates describes their design activities & personnel qualifications in the field of research & power nuclear reactors.

22 Plant Layout. Brochure from F. Ward Harman Assoc. describes modern methods for plant layout solution by means of two- & three-dimensional equipment models, templates, & assorted accessories.

23 Electronic Equipment. A folder containing product sheets & complete specifications on specialized electronic equipment such as alpha, beta, gamma counter tubes, & voltage regulators. Booklet describes the research & development services of Anton Electronics Labs., Inc.

(Continued on page 72)

DEVELOPMENTS OF THE MONTH *(Cont.)*



110 CATALYSTS MADE OF THE PLATINUM GROUP METALS now allow manufacturers to utilize general advantages of these catalysts such as product purity, high activity at low temperature & pressure, & maximum yield. The technical division of a new Baker & Co. bulletin on these metals has detailed sections on catalytic oxidation of ammonia, gas purification, measurement of impurities in gases, & supported platinum metal catalysts in petroleum processing. The company is the world's largest manufacturer of platinum group metal catalysts & has done much active research, development & production in this specialized field. Circle Number 110 on Data Postcard.

(Continued on page 72)

24 High Speed Pulverizers. A condensed bulletin from Pulva Corp. describes their full line of high speed pulverizers. Units are available in five sizes ranging from ¾ to 75 h.p.

25 Hot Oil Systems. Electrically heated oil systems are the subject of a bulletin from Parks-Cramer Co. These fully automatic Merrill process systems produce oil temperatures in the range of 150 to 600° F. at low pressure in a compact, completely assembled package unit. When connected it is ready for immediate service.

26 Ion-Transfer Membranes. A recently released bulletin from Ionics, Inc. indicates a variety of process applications where electrical energy & ion-transfer membranes are useful to concentrate, dilute, separate, recover or purify process or waste solutions. Described in bulletin are principles of ion-transfer, required power consumption in certain cases, equipment & services available.

27 Chlorine Handling & Storage. A wall chart listing 50 successful suggestions for safe handling & storage of chlorine in 100 & 150 lb. cylinders & ton containers is offered by Diamond Alkali Co. Of interest to production men, safety engineers, purchasing directors & others responsible for chlorine storage & handling.

28 Fabricated Alloy Products. Rolock Inc. have just issued an illustrated & comprehensive combined catalog on heat- & corrosion-resistant fabricated alloy products. Products are fully described & book has sections on furnace muffles, trays & fixtures, retorts & pit-type furnaces, etc.

29 Packaged Water Tube Boilers. Described in a recently issued catalog from Superior Combustion Industries, Inc., are packaged water tube boilers for capacities to 50,000 lb./hr. Complete data & dimensions are included for boilers ranging from 8,000 to 50,000 lb. of steam/hr. Firing is oil, or gas, or both.

30 Solenoid Valves. Catalog on solenoid operated Crescent valves from Barksdale Valves. Listed by major service condition as air, 4-, & 3-way to 150 lb./sq.in.; air, light oil & water, 4- 3-way & dual pressure to 150 lb./sq.in. Includes valve characteristics, flow patterns dimensions, illustrations.

31 Gyratory Screen. Model CS-1 gyratory screen designed to give efficient separation of dry granular products into predetermined grades. For use in chemical process & food industries. Easily installed, operated & maintained. Binder insert bulletin. Allis-Chalmers Mfg. Co.

32 Industrial Fans. From American Blower Corp. catalog on series 106 industrial fans. Complete information, illustrations, other details.

33 Water Treatment. Graver Water Conditioning Co. have available a technical reprint on "Selection of Chemical Treatment for Water Clarification." Mainly devoted to selection of proper coagulant & coagulants available. Table compares characteristics of these materials.

√ **CHECK** *your Data Service requests on the handy postcard on page 65 to*

▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

34 Disc Roll Mill. Hardinge Co., Inc. bulletin 52 covers the disc roll mill. This binder insert includes schematic drawings, illustrations & details of operating principle, construction, applications & other details.

35 Wet Pit Pumps. Yeomans Brothers Co. announce revised catalog on line of heavy duty wet pit pumps for applications such as drainage, flood water, effluent boiler blowoff, acids & alkalis. Well illustrated, book gives tables, shows curves & discusses design features. A section on standards is condensed list of metals used in pump construction.

36 Pressure Meters. Granco pressure meters are subject of bulletin from Granberg Corp. Three types: positive displacement; double-case; & a late model the Duo-Rotor. Capacities to 30,000 gal./min. Contains dimensions, specifications, engineering data, plus pressure drop charts.

37 PVC Blowers. Subject of new 20-page brochure from Industrial Plastic Fabricators Inc. is unplasticized rigid PVC blowers. These centrifugal units are designed & built to withstand most chemical fumes & polluted air in temperature range of 40 to 140° F. Four impeller diameters: 9½, 13¾, 19, & a new 27 in. size.

38 Welding Procedures. A binder insert technical data card which summarizes recommendations for joining, by arc welding procedures, various tubing steels is made available by Babcock & Wilcox Co. Indicates proper electrodes to use & provides information about preheating & postwelding heat treatments.

39 Rotameter Kit. Designed for service to 3,000 lb./sq.in. at 200° F, a high pressure rotameter kit from Brooks Rotameter Co. Feature is unique equalizing vent permitting use of glass metering tubes at elevated pressures without fear of tube rupture. Stocked in steel & 316 stainless steel. Special materials & optional equipment available.

40 Experimental Agitator. Specifically designed for bench scale & pilot plant mixing operations & presented by Chemineer, Inc., an experimental agitator. Determines agitation requirement of a particular process operation & is efficient in basic study of mixing as a unit operation. Variable speed transmission with output from 0 to 1,100 rev./min. Furnished with twenty-two calibrated impellers including standard conventional turbine, propeller, & paddle styles.

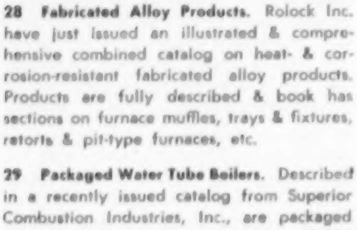
41 Absorption Refrigerating Machines. A new line of large capacity automatic absorption refrigerating machines for production of chilled water from steam announced by Carrier Corp. Sizes from 100 to 700 tons. for use in air conditioning & process cooling systems. Operable from push button, thermostat or time clock.

42 Sintered Filter. Said to be of unique design & remarkable versatility a sintered filter developed by Purolator Products, Inc., handles fluids ranging to 1,000° F., can take flow rates comparable to any high temperature filter with lower differential pressures & better degree of filtration. Said to remove particles as small as 1 micron in size from wide range of fluids including such acids as hydrochloric, sulfuric, phosphoric, as well as alkalies. May be custom built of stainless steel, Monel, or other metals. Features controlled permeability & uniform porosity.

43 Temperature Conversion Table. Printed on heavy, bristol-board-like stock & laminated for added protection, a binder insert temperature conversion table ranging from —460 to +4,000 degrees is available from Thermo Electric Co., Inc. Converts degrees Fahrenheit to Centigrade & vice versa. Also shows temperature ranges of various sensing elements.

(Continued on page 74)

DEVELOPMENTS OF THE MONTH *(Cont.)*



111 A GLOSSARY ON ATOMIC ENERGY TERMS has been issued by The Esso Research and Engineering Co. The pocket-size booklet "101 Atomic Terms" is the first attempt of its kind to do the job in simple terms. Covering terms from A to Z, definitions of photon & cloud chamber, as well as the interesting slang terms such as cutie-pie, pig, & coffin, are covered. The use of such slang terms is exemplified by the fact that to expose chemicals to intense radiation you send a rabbit into a pile, loaded with slugs. Circle Number 111 on Data Postcard.

(Continued on page 74)

44 Portable Pump & Motor Unit. A close-coupled, portable electric motor & pump unit with dry suction lift of approximately 15 ft. introduced by Jabsco Pump Co. Consists of stainless steel self-priming pump mounted directly on shaft of a ¼ h.p., 1,725 rev./min. motor. Has neoprene impeller with ½ in. inlet & outlet ports to fit standard piping. Operates on 115 a.c., 60 cycle, single phase. Capacity 10 gal./min. against 10 ft. head for pressures to 20 lb./sq.in.

45 Constant Support Hangers. Grinnell Co., Inc. announces an extended line of model R constant support hangers with capacities 31 to 32,267 lb. Units permit expansion & contraction of piping systems, through heating & cooling cycles, without development of dangerous stresses. Line offers increased supporting forces or greater travel within given size frame to provide for required load. Nine frame structures available.

46 Transmitting Potentiometer. Industrial Controls Div., Manning, Maxwell & Moore, Inc. announce a transmitting potentiometer based on a new operating principle. Permits measurement & control of low voltages while drawing negligible current from source. Available as a thermocouple pyrometer. Has simplest possible circuitry.

47 Continuous Dust Filter. Announced by The Day Co. a dust filter of unique design which permits highly efficient, automatic continuous filtering. Employs Hersey principle in that it deposits dust on the outside of the filter sleeves. Twelve sleeves of felted filter media are used.

48 Compressor. New two-stage inter-cooled compressor for use wherever high pressure, high-capacity compression of either air or other gases is required. Capacities 100 to about 4,000 cu.ft./min. & ranging from 15 to 600 h.p. Includes pair of positive displacement, axial-flow blowers, arranged to work in two stages. Continuous air seal provided by proximity of male & female rotors. Eliminates friction & need for internal lubrication. Standardized by Read-Standard Corp.

49 Stainless Steel Pumps. Called Flex-Alloy a line of self-priming stainless steel rotary pumps without stuffing box or mechanical seal announced by Vanton Pump & Equipment Corp. Use is for corrosive solutions, abrasive slurries & fluids which must be maintained free from contamination. Available in either type 304 or 316 stainless, as well as special alloys. Handles solutions at temperatures to 265° F.

50 Thermocouple. To meet the demand for a suitable measuring device in high temperature & pressure services Trinity Equipment Corp. have developed a purge type thermocouple. Meets the need for a unit to be used under temperature conditions to 2900° F. at high pressures in reactors, catalyst beds, etc. Consists of a silica free ceramic tube which houses the platinum purge tube & platinum-platinum rhodium couple.

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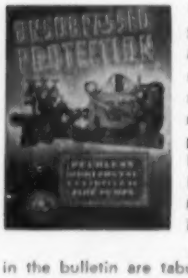
DEVELOPMENTS of the month (Cont.)



112 FIRE PUMP SELECTION CHARTS & typical fire pump specifications are some features of a new & expanded 36-page bulletin published by Peerless Pump Div. of Food Machinery and Chemical Corp. The fire pump selection charts in the bulletin are tabulated in two ways: first listed are those pumps approved by Underwriters' Laboratories, Inc. & by Factory Mutual Fire Insurance Companies; second, all pumps are listed in groups according to type of drive, including electric motor, steam turbine, gasoline & diesel engine. Cross section views & dimension drawings are given. Sizes & types listed cover the entire capacity range from 500 to 2,500 gal./min. with a pressure range at rated capacities from 40 lb. through 340 lb./sq.in. Circle Number 112 on Data Postcard.

90 Tagged Organic Chemicals. New isotope tagged organic chemicals added to availability list by Tracerlab, Inc. Many tagged with either C^{14} or S^{35} now available for first time from a commercial radioisotope laboratory. List & monthly publication "Tracerlog" upon request.

91 Technical Bulletin on TME. Reports on properties & uses of trimethylolethane, a synthetic, solid trihydric alcohol. Published by Heyden Chemical Corp. booklet covers use of TME as raw material in manufacture of alkyds, drying oils, polyesters, etc. 23-pages with tables, properties, formulae.

92 Pipe Dope. Teflon-based pipe dope has given excellent performance with corrosive liquids minimizing seizure or galling. Particularly useful with stainless steel & other high alloy fittings. Eco Engineering Co.

93 Activated Carbon. Brochure on G-32 activated carbon shows typical flow sheets for solvent recovery, air & gas purification, gas separations, etc. Girdler Co.

94 Chlorinated Polyphenyls. Data sheet on three chlorinated polyphenyls. For plasticizing PVA adhesives. Compounds are light-colored liquids mobile at room temperature requiring no pre-melting. Monsanto Chemical Co.

95 Lithium Hydroxide. Trona lithium hydroxide for use in petroleum, storage battery manufacture, gas absorption, & lithium salt. Issued by American Potash & Chemical Corp. Includes physical properties & typical chemical analyses.

96 Synthetic Rubber Latices. From U. S. Rubber Co. binder insert 8-page technical folder describing product & uses.

97 Synthetic Fluids & Lubricants. Materials are fully described with tables & properties in new 52-page booklet from Carbide and Carbon Chemicals Co. Applications & characteristics of these polyalkyleneglycol derivatives given in detail with charts & tables.

98 Corrosion & Contamination Problems. Nickel lining applicable to pipe from 1½ to 24 in. diam. illustrated & described in 8-page booklet on Bart Lectro-Clad process. Contains pure nickel with well known corrosion resistance. Bart Mfg. Corp.

99 Ten New Chemicals. Recently added to line of Distillation Products Industries, ten new chemicals. Additions include maleopimaric acid, maleic anhydride adduct of a resin acid isomer.

100 High Purity Amides. Three new surfactant diethanolamides have been announced by Stepan Chemical Co. Minimum guaranteed amide content is 90%. Technical data sheets cover specifications & shipping information.

101 Industrial Solvent. New material said to have cleaning properties close to those of carbon tetrachloride but up to 20 times less toxicity, announced by Speco, Inc. Non-flammable Vinsol is recommended for removing oil, grease, wax & tars from tools & equipment even in confined areas.

102 Polyhydric Alcohol Esters. New 1956 issue of catalog "Esters" by Glyco Products Co., Inc., describes fatty acid esters of glycerol, glycols & polyethylene glycols, including tables of physical & chemical properties. Products are used as emulsifying agents, stabilizers, defoamers & plasticizers in many fields.

103 Ethanolamines. New 48-page booklet on ethanolamines gives extensive physical & chemical data including vapor pressures & densities. Nitrogen Div., Allied Chemical & Dye Corp.

104 Cabflex HS-10. Availability in commercial quantities of Cabflex HS-10, said to be the first low volatility phthalate plasticizer, announced by Godfrey L. Cabot, Inc. An alkyl aryl phthalate having volatility one-half that of di-decyl phthalate, fills need for a monomeric plasticizer of high stability & permanence. Requires no antioxidant. Samples available.

NUCLEAR NEWS

CITIZENS' PANEL REPORT ON ATOMIC ENERGY

Recently, the McKinney Panel made its report to the Joint Committee, which is now holding hearings to evolve proposals for changes in the Atomic Energy Act. Following is C.E.P.'s resume of the conclusions and recommendations of the Panel Report:

ATOMIC POWER

Present development program deficient in that demonstrations of small and medium size types are not now under way. By 1975 atomic power is expected to amount to only 20 to 40% of presently installed capacity (U.S.).

CONTROLLED THERMONUCLEAR POWER

The vast area of scientific and engineering required for its development would seem to warrant the maximum interplay of ideas from the widest number of individual contributors.

RADIATION PRESERVATION OF FOOD

Not likely to replace other methods to any substantial extent. Present development program should be continued.

ATOMIC PROPULSION

Commercial Ships—A program for economic evaluation should be basis for decisions regarding the construction of any substantial number of ships.

Commercial Aircraft—Competitive applications unlikely until military prototype experience is acquired.

Locomotives—Offer no economic advantages.

Motor Vehicles—Not feasible.

PROCESSING

Heat for industrial processes *could* be significant. No active research and development program is in progress. Private industry must evidently bear the primary responsibility for such; however, only AEC has facilities required to conduct the metallurgical research essential to the development of high-temperature reactors.

Energy from atomic radiation may be very important to the chemical and other industries. AEC support of fundamental exploration should be stepped up. Development of specific applications will be carried out by industry.

Atomic space heating does not appear economically competitive.

Radioisotope use is expected to be large in the years ahead.

MEDICINE & PUBLIC HEALTH

Higher priorities for additional research, training, and treatment facilities, more extensive availability of radio-

(*Continued on page 76*)

NUCLEAR NEWS

ATOMIC ENERGY

(*Continued from page 75*)

chemicals, full exchange of information, and a nation-wide educational program.

ABROAD

Executive Branch should establish specific research and development goals to meet the needs of friendly nations. AEC should center its responsibilities in the international field in one alert, forward-looking organizational unit. Adequate research and development facilities should be provided to friendly countries, accompanying research reactors supplied by the U. S.

Other nations should decide for themselves the rate at which they wish to apply atomic power and other uses of atomic energy to their own economies. Recommendations:

(1) That the U. S. promptly convene regional conferences of our bilateral partners for the immediate establishment of realistic goals for the installation of atomic electric generating plants in specific countries, (2) that the U. S., in issuing such invitations, announce that it is prepared to furnish nuclear fuels, provide necessary technological assistance, and permit contracts for the installation of at least 1 million kw. of atomic generating capacity outside the U. S. as soon as possible—by 1960, (3) that financial assistance be made available through normal governmental and private channels, not through the AEC, and (4) that atomic power plants constructed under these programs be subject to interim control plans involving appropriate inspection agreed upon by each participating bilateral partner, and requiring reprocessing of spent fuel and recovery of Pu or U-233 in the U. S.; materials thus recovered to be earmarked for further expansion of peaceful uses.

RESEARCH & DEVELOPMENT

Basic research in universities given generous support, with AEC contracting for this purpose. Total research should be expanded. To aid industry planning, AEC should announce its future objectives and programs. Present AEC laboratories should be supported.

MANPOWER

Determined methods should increase the output and quality of scientists and engineers for development of atomic uses. This would include financial support, wider use of AEC facilities for training, and addition of further research reactors and other facilities.

INSURANCE

Hazards should be further evaluated, and the Government should encourage the insurance industry to develop ways of meeting atomic-insurance problems entirely within the concepts of private enterprise.

(*Continued on page 91*)

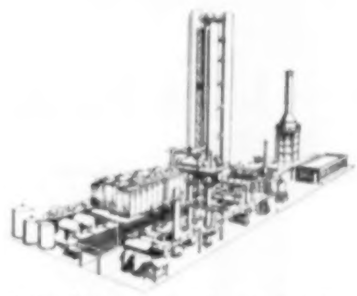
REVOLUTIONARY STYRENE PLANT FOR COSDEN

To be engineered and built by Badger Manufacturing, Cambridge, Mass., the new styrene monomer plant of Cosden Petroleum will employ never-before-used separation techniques requiring 200-foot fractionation towers.

To cost $3 million, produce 20 million pounds per year of styrene monomer for plastics manufacture, the new plant of Cosden at Big Spring, Tex., will use modern, improved techniques of separation including "ultra-fractionation" for the recovery of ethyl benzene directly from petroleum stocks, i.e., from mixed xylene streams.

Ultra-fractionation for the recovery of ethyl benzene has never been done before, and eyes of the entire industry are carefully watching Cosden's plant. Usual method of producing ethyl benzene has been to alkylate benzene with ethylene.

The revolutionary nature of the process, requiring towers some 200 feet high (among the tallest ever erected), has caused considerable stir in the industry,



Engineering drawing of the unique styrene plant to be built by Badger at Big Spring.

has engineers waiting for the unit to go on-stream at the end of 1956.

For Cosden, the plant represents a major diversification of products.

GIANT, NINETY-FOOT TOWER RAISED IN UNIQUE OPERATION

306-ton de-resining tower raised into position at Humble Oil's Baytown refinery, in midst of operating refinery, in only 8 hours with minimum down-time.

The fabrication and erection of the giant de-resining tower by M. W. Kellogg, in addition to being in itself a monumental construction operation, had three unique features.

Contrary to conventional practice in which large towers of this type are fabricated in the field thus eliminating the problem of erecting a finished tower, cost considerations made it desirable to fabricate the tower in the shop. This effected considerable savings by eliminating welding, stress relieving and radiographic inspection in the field.

Since the unit was shipped in one piece, the problem of calculated moving loads and stresses imposed during lifting had to be considered. These were overcome by temporarily reinforcing and modifying the tower before it left the shop. Special bracing inside the skirt, and heavy bearing plates attached at the point where the tower would contact the carrying sled at greatest weight, allowed the tower to take the load of the lift.

Conventional "brute force" methods of unloading a cylindrical vessel were discarded in favor of a special method with specifically designed foundations, gin poles, cranes, and special rigging.

IMPACT OF ATOMIC ENERGY ON CHEMICAL INDUSTRY

Survey shows impact is strong, with new products, need for more chemical engineers, becoming major factors.

Changes in the chemical industry as a result of the impact of atomic energy will be "evolutionary rather than revolutionary," but there will be changes, some already apparent, according to a recent survey of the Manufacturing Chemists Association.

Up to the point where mass changes into energy, atomic industry is a branch of the chemical industry. New chemical markets will certainly result from by-products of nuclear processes, the needs of reactors for fuel and other materials will have to be met as a private atomic industry grows, and the greater use of nuclear energy will probably mean that products not now produced commercially will be needed in tonnage quantities.

Manpower

The 75 chemical companies surveyed by MCA had some definite views on specific areas of atomic impact on the process industries.

On the question of already-short engineering manpower, the survey showed that the companies feel that growth of the nuclear field will compete seriously for the supply of chemical engineers. Already the "appeal of the new and unknown" is attracting some 10% of chemists and chemical engineers to atomic facilities. The problem is not a minor one since it will certainly further decrease the supply of engineers for present industry and teaching.

The consensus of the 75 companies was that while recent declassification efforts by AEC have provided more freedom of operation to private enterprise, further declassification would assist the progress of peaceful uses of atomic energy. (See report of special Citizen's Committee, page 75 of this issue.)

The reporting firms held that while radiation is likely to be a useful tool in the chemical industry, it is unlikely to be a dominant factor. The use of isotopes and tracers already quite significant, should grow, particularly when the cost of radiation energy from nuclear processes becomes more economically attractive. Fields of specific application named by the companies were food sterilization, pharmaceuticals, medicines, polymerization and agriculture.

REACTOR DESIGN, GRADUATE NUCLEAR ENGINEERING IN NEW PROGRAMS

Two of the latest additions to the rapidly growing educational opportunities in the nuclear field have been inaugurated at Columbia and Univ. of California.

Indicative of the growing field of nuclear engineering, the University of California began full master's and doctoral programs in nuclear engineering last fall, and Columbia has just expanded the study of the design of nuclear reactors for the spring term.

At Columbia the expanded program will bring graduate students and engineers into contact with the men who helped design and operate the great atomic plants at Hanford and Savannah River, with members of the atomic energy division of Du Pont, and with such men as Kaplan and Manowitz of Brookhaven, many of whom will be the course lecturers.

T. B. Drew, executive officer of Columbia's department of chemical engineering, stressed that while certain information must still be held back for security reasons, it is now possible to treat the majority of the most interesting problems involved in reactor design.

In the Univ. of California program, the university is working in cooperation with the U. C. Radiation Laboratory, both at Berkeley and Livermore, and the lab work includes many experiments with the Livermore water boiler reactor, as well as work with the giant automatic computers, such as Univac, in the field of reactor design.

The work is at an advanced level at California, strong mathematical background is required. Subjects are: nuclear reactor physics, elements of heat and mass transfer, power cycles and systems, advanced applied mathematics, seminars involving various experts in the field, advanced reactor physics and nuclear power plant design, process heat and mass transfer in nuclear engineering, materials in nuclear reactors, reactor kinetics and automatic control, and a year of nuclear engineering laboratory.

CORRECTION

The photograph of an exhibit at the recent A.I.Ch.E.-sponsored Atomic Exhibition shown on page 53, photo No. 10, in the January issue and designated as the Allis-Chalmers exhibit is actually the Alco Products exhibit, showing the Army Package Power Reactor being built by Alco at Fort Belvoir, Va.

The second Bioengineering Symposium will be held at Rose Polytechnic Institute in Terre Haute, Ind., April 20-21. Jointly sponsored by Rose Poly and the local section of A.I.Ch.E., the symposium will review the developments and present status of the bioengineering field. Plant trips are scheduled, the program will include: Some Nonpharmaceutical Uses of Anti-Biotics, Equipment for Cultivation of Fastidious Microorganisms, Bioengineering Problems of Poliomyelitis Vaccine, The Significance of Sulfate Reducing Bacteria in the Production of Petroleum, and Bioengineering of Waste Disposal. □

Nitrogenous fertilizer project, including 100 ton/day ammonia plant and 90 ton/day urea plant, is being designed by Chemical Construction Corp. for Nihon Gas Kagaku Kogyo, K.K., Tokyo. The urea plant will incorporate Chemico's full recycle process while the ammonia plant will be based on high pressure reforming of natural gas. □

Expansion at La Crosse, Wisc. and Scranton, Pa., by the Trane Co. in its plants there will cost the company an estimated $1,300,000.

New facilities will be used primarily to produce more centrifugal refrigeration compressors, water chilling units, and air conditioners. □

New construction at AEC's Rocky Flats, Colo., plant will cost $13,500,000, will take over a year to complete. The plant, operated for AEC by Dow Chemical, will have the additional construction engineered by Catalytic Construction Co., Philadelphia, Pa., built by Swinerton and Walberg, San Francisco. □

Capacity will be doubled soon at National Starch Products' Meredosia, Ill., vinyl acetate resin polymerization plant. □

First full-scale plant for the manufacture of Du Pont's new chlorosulfonated polyethylene rubber, called Hypalon, will be built at Beaumont, Tex. □

The new Engineering Development Center of The Lummus Co., designing engineers and constructors for the chemical and petroleum industries, is located in Newark, N. J., and will be used primarily for pilot plant operation and process development work.

AUTOMATIC LOGGING AT BAYWAY

Esso Standard installs electronic data integrating system at its Bayway (N. J.) refinery, saves time, increases accuracy.

Designed by Minneapolis-Honeywell Regulator Co. for Esso, the new high-speed electronic system will log Bayway's operating data, add it up at the day's end, and keep a robot eye on quality in the meantime. Result of nine months research and engineering work, the system can range in price from $10,000 to $50,000.

At Bayway the system gathers data for the production of a commercial solvent, automatically logging such operating data as temperature, pressure, flow, power consumption and product quality. It stores up figures for flow and power used and adds these at the end of the day. All data, translated into numbers, is fed automatically to electric typewriters, and flow and power measurements are punched on tape for later use in cost accounting operations.

When not actually recording, the system monitors a number of critical points, keeping track of conditions, picking up deviations as they arise.

Quality, in this case purity of the solvent, is measured by converting the desired quality into an electrical signal, picking it up on recording machines. If it slips below the desired characteristics an alarm sounds.

Minneapolis-Honeywell stresses that the system was designed to supplement, not supplant, the regular operators by centralizing all operating data at one point, minimizing the strain on operators, providing complete accuracy regardless of emergencies and the speed of the variations in the process.

Installed in the central control room at Bayway, the system comprises two 6 ft. × 7 ft. × 2 ft. steel cabinets, is laid out with conventional graphic panel control boards.

The multi-million-dollar National Gypsum plant at Westwego, La., is nearing completion, will go on stream in the Spring. ☐

New plant for the large-scale production of adipic acid is now under construction by Monsanto at the Luling, La., Barton Plant of Lion Oil, a division of Monsanto since the recent merger.

The unit will cost several million dollars, is expected to be on stream by early 1957, is fully integrated with Lion's raw materials facilities. ☐

Second Annual Statistical Engineering Symposium, sponsored by the Chemical Corps Engineering Command, will be held at Army Chemical Center, Md., April 26-27.

Mutual understanding of the problems in the field among Government, industry and education is again the theme of the session, with two general areas receiving main attention this time: theoretical development and practical application of the various principles involved. □

All the latest refinements will be built into the planned new polyethylene plant to be built in Brazil by Union Carbide and Carbon. To be located at Cubatao, near Santos, the plant will be owned and operated by Carbide's wholly-owned subsidiary, Union Carbide do Brasil, S.A., will get its ethylene from the nearby refinery and ethylene plant of Petrobras, the Brazilian government agency that controls major refining operations in that country.

The plant will supply all Brazil's polyethylene needs over the next five to ten years, is designed for easy expansion. □

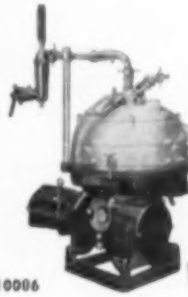
A seminar primarily for engineers responsible for the operations of electrostatic precipitation equipment will be held at Pennsylvania State University, June 11-15. □

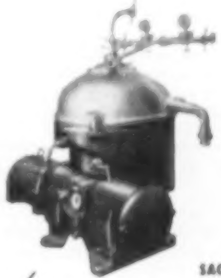
Construction of a plant for mining and processing titanium-bearing ore will soon be started in Virginia by Metal & Thermit Corp., New York. Construction will start in Spring, will cost about $750,000. □

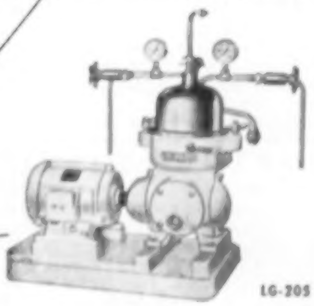
Indicating the fast-growing nature of the silicones field and Union Carbide's expanding activities in that area, Carbide has just formed a Silicones Division to take over the development, manufacture and sale of silicone products.

Capacity of the company's new silicone plant at Long Reach, W. Va., will be enlarged by some $1 million worth. □

New paints based on Pliolite S-5 resin are being used on 19 new tank cars of Union Tank Car Company, will transport Goodyear latices containing as much as 10% alkali. The new paints are resistant to high acid, salt and alkali exposure, will give boost to tank car transportation of corrosive chemicals.







INDUSTRIAL NEWS

PULLMAN TO PRODUCE POLYOLEFINS BY NEW PHILLIPS PROCESS

License agreement signed, production expected by late 1957 or early 1958, production of polypropylene possible.

Designed to continue Pullman's policy of diversification, the new agreement with Phillips will broaden the base of Pullman's subsidiary, M. W. Kellogg, in the plastics field.

The Phillips polyolefin process differs from most in commercial use in that it employs an entirely new type of catalyst. Perhaps most important is that the new process produces not only the rapidly expanding low-pressure polyethylene, but copolymer mixtures of olefins and polypropylene, on which Phillips recently took out a patent. Pullman expects to investigate the development of a whole new spectrum of resins from olefins, as well as produce the new type polyethylene.

Among the outstanding advantages of low pressure polyethylene that induced Pullman to enter the field is the fact that it can be heated to sterilization temperatures without deformation. Others are its higher tensile strength, greater rigidity and higher impact strength.

A new engineering and pilot production building at Towanda, Pa., is in the planning stage at Sylvania. Being built for the company's Tungsten and Chemical Division, it is designed to meet the requirements of the Division's expanded activity in the field of semiconductors, phosphors, chemicals, and metallurgical products. ☐

Three new plants for the production of industrial gases are scheduled for completion this year by Air Reduction Company. To be located at Chicago and Alton, Ill., and Calvert City, Ky., the plants are part of a $16 million expansion program planned for 1956. ☐

A $1,500,000 Chemistry Research building is part of a new $5 million building program recently announced by Armour Research Foundation of Illinois Inst. of Technology. ☐

A multi-million-dollar expansion program is underway at the Bonnie phosphate plant of International Minerals and Chemical Corp., Bartow, Fla. When the expansion is completed the Bonnie plant will be able to produce 500,000 tons of product, primarily triple superphosphate and feed grade dicalcium phosphate. ☐

EXTRACTION PLANT TOURS COUNTRY

British engineering firm sends scaled-down operating model of new extraction plant on motor tour of American industrial plants.

Now touring the country towing a ¼-size model of the new Bentall Extraction Plant are two officials of E. H. Bentall & Co., Ltd., Maldon, England. Plans include visiting drug, chemical, essential oils, paint, leather and food industry plants, for which the extractor is particularly adapted.

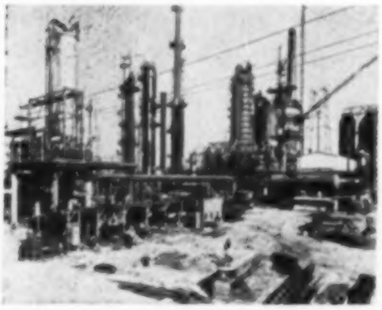
Bentall claims that the machine uses only some two-thirds the horsepower normally required by continuous worm presses now operating. The machine operates on the worm expellor principle, is especially valuable for extracting oils and fats, reducing drying and transport costs by expelling moisture from almost any substance.

Costing $5,600 at the factory in England, the unit was originally designed for agricultural product use, has been expanded into the industrial field.

No actual construction has been authorized, but a study is underway by Du Pont to determine whether or not a new plant capable of producing 35 million pounds annually of heavy denier nylon yarn for industrial use should be located at the company's Richmond, Va., site. □

A new unit to produce vinyl esters in commercial quantities is now on stream at Carbide and Carbon Chemical's Niagara Falls, N. Y., plant. Culmination of four years' development work, the unit will produce tank car quantities of vinyl propionate, vinyl butyrate and vinyl 2-ethylhexoate. □

Small volume shipments of methyl mercaptan can now be handled at Pan American Chemical Corp.'s new multi-million-pound plant. □



Finishing touches are now being put on the new fluid catalytic cracking unit and gas recovery facility at Gulf Oil's Port Arthur, Tex., refinery by M. W. Kellogg. The new installation has a daily capacity of nearly 70,000 bbls.

PENTAERYTHRITOL EXPANSION TO USE NEW PROCESS

Construction is underway on new Heyden Chemical plant at Fords, N. J., production scheduled for March, 1957.

Heyden's fourth major pentaerythritol expansion since 1939, the new plant will produce 25 million pounds per year, is being erected adjacent to the company's present plant at Fords which produces formaldehyde and other organic chemicals. Reason for location: availability of raw materials and near principle consuming markets.

Main feature of the new process to be used in the plant is its complete flexibility in producing any grade or type of pentaerythritol. This is an important factor today in the rapidly expanding and highly diversified market for the product. Years of intensive laboratory, pilot plant, and field work have gone into the development of the process specifically to gain this flexibility. At the same time the new process assures high quality and uniformity in each grade and type.

Recent expansion of manufacturing facilities at the Huntington, Ind., plant of Baldwin-Hill, includes newly designed equipment for making mineral wool felts having greater densities than those commonly produced up to now.

Capable of compressing a 30-inch thickness of loose mineral wool to 2 inches, the new machines will produce improved thermal insulating materials for industrial and home use. □

Erection of a plant for the production of low-pressure polyethylene in Brazil has been authorized jointly by W. R. Grace and Farbwerke-Hoechst, A.G., Frankfurt am Main, Germany.

This is another step in the plans of the two companies to develop a full line of essential chemicals in Brazil. □

A new tall oil plant will be built by Rayonier at its chemical cellulose operation at Jesup, Ga. □

Biochemical Procedures, Beverly Hills, Calif., is the new West Coast Laboratory of Foster D. Snell, New York. □

If the outcome of present studies is encouraging, Du Pont may build a new 40-million-pound per year "Orlon" acrylic fiber plant at Waynesboro, Va. This would bring the company's "Orlon" production up to 100 million pounds per year. □

CHEMICAL INDUSTRY LEADS BASIC RESEARCH, SCIENTIFIC EMPLOYMENT

National Science Foundation report shows chemical industry far out in front in the magnitude of its basic research program, shows industry also leading in number of scientists employed.

Estimated at $38 million, the basic research cost for the chemical industry represented 25% of the total expenditure for basic research by all industry in 1953. In addition, the chemical industry also leads in the percentage of total research cost spent on basic research with a figure of 10%.

The chemical industry also leads in the number of scientists and engineers employed. In January, 1954, there were 62,700 scientists and engineers in the industry, or one out of 12 of the total chemical employment. Of these, the largest number, 26,000, were engineers. The second largest number, 23,400, were chemists.

Initial buildings in a new chemical research center to be built by Spencer Chemical near Kansas City, will be a main chemical research laboratory, a process development pilot plant, and an experimental greenhouse. Fifty to 65 engineers and chemists will be initially employed at the new center. □

Now under construction, American Cyanamid's new 200,000 ton per year triple superphosphate plant at Brewster, Fla., will be completed in mid-1957. □

Bids will be taken early this spring for the construction of a new "L" shaped engineering building for the Trane Co., La Crosse, Wisc. □

U. S. Rubber expects to spend some $36 million for new plants and equipment in 1956.

A sign of the rapid recovery of the French petrochemical industry is the new 30 million dollar expansion program for Naphtachimie's ethylene oxide plant in Lavera, France. Here, Dr. Pierre Rube (3d from left), head of Naphtachimie, signs the design and engineering contract for the new installation with Scientific Design Co., Inc.

FURTHER DETAILS ON GETTING INTO NUCLEAR FUELS REPROCESSING

The following is taken from remarks by W. Kenneth Davis, Director of the Division of Reactor Development, AEC, at the Second Power Reactor Fuel Processing Symposium, Idaho Falls, Idaho, January 18-20.

The program which the AEC has developed for encouraging the industrial processing of irradiated fuels from privately-owned reactors is briefly as follows:

All available AEC technology on chemical processing will be made available to industry, through appropriate means such as reports, seminars, and plant visits in accordance with access permit regulations.

A description of the types and amounts of miscellaneous irradiated fuels expected to be available in the foreseeable future from certain AEC reactors, from military reactors, from privately-owned research reactors and from foreign sources, will be made available. (Now classified.)

The Metal Recovery Plant at Oak Ridge and the Idaho Chemical Processing Plant were built primarily for *developmental* purposes and for the recovery of source and special nuclear materials from government reactor fuels and the AEC would prefer *not* to employ them as service facilities for processing fuels from the atomic power industry.

The AEC will consider making available to industry for set periods of time certain fuels for processing, including fuels from: Materials Testing Reactor, Experimental Breeder Reactor No. 1, Submarine Thermal Reactor Mark I, Submarine Advanced Reactor, Large Ship Reactor, Submarine Intermediate Reactor Mark A, Bulk Shielding Reactor, Pressurized Water Reactor, Sodium Reactor Experiment, Experimental Breeder Reactor No. 2, Experimental Boiling Water Reactor, Army Package Power Reactor, Engineering Test Reactor, Homogeneous Reactor Experiment No. 2, X-10 reactor at Oak Ridge National Laboratory, Brookhaven National Laboratory reactor, Submarine Thermal Reactor Mark II, Submarine Intermediate Reactor Mark B, Submarine Advanced Reactor and Large Ship Reactor, university, institutional and industrial research reactors, and foreign reactors.

The AEC will permit the use of its facilities by industry for development work and other related purposes, with full cost of such use to be recovered by

the AEC. (Patent provisions to cover the use of such AEC-owned facilities would be incorporated in such an arrangement.)

The AEC will invite proposals from industry (in about 12 to 18 months) for the design, construction, and operation of chemical processing plants capable of processing one or more of the fuel types which will be employed in projected licensed power reactors, plus limited quantities of AEC irradiated materials. Industry would be advised to include in these proposals a description of their plans for research and development facilities, staff and program. The AEC fuel types and quantities desired, the duration of the proposed contract with the AEC, and the prices at which they will be processed for the Atomic Energy Commission would be specified in each proposal.

Evaluation of Proposals

Industry proposals will be evaluated by the AEC in relation to the following general criteria, which will be made a part of the original invitation:

1. **Advancement of the art:** This will include consideration of the economics, versatility of plant for a wide range of fuel types, and development program proposed for both before and after plant start-up.
2. **Prices:** Prices for processing AEC fuels will be evaluated against those of all other proposals for processing the same fuels, and must not exceed the fair value of the services performed. Prices will be compared with the full cost of performing the same services in AEC facilities.
3. **Capacity and start-up date of plant:** Preference will be shown plants with early start-up dates.
4. **Responsibility for disposal of wastes:** The manner in which the waste disposal problem will be handled and plans for development of methods will be of major importance.
5. **Agreement with private reactor operators needed;** no proposal will be considered which does not involve the processing of fuel from at least one licensed power reactor.
6. **Assurance against abandonment of project.**

Questions and Answers

Many questions have been raised on the chemical processing program of which a few, with ramifications, are covered below:

Question 1. What does the AEC Reactor Development Division consider to be a reasonable price for fuel processing?

Answer 1. The cost of each segment of the power reactor cycle has to be brought down to a level which will permit the production of economic power on an overall basis. The Division has been using a target figure of 2 to 3 mills/kwh for total fuel costs. This cost includes fabrication, burnup and degradation, process-

(*Continued on page* 88)

FUELS REPROCESSING

(*Continued from page* 87)

ing, waste disposal, all losses and finally all inventory charges. It is somewhat arbitrary to assign a figure on chemical processing at this time, but we have been using a target value of approximately ½ to 1 mill/kwh for processing. This would include such costs as inventory during processing, processing losses, waste disposal, conversion to metal and shipping costs of fuel elements as well as recovered products. For the AEC fuels which you might process, your charge must not exceed the fair value of the services performed.

Question 2. What are the AEC fuel processing costs?

Answer 2. The AEC's preliminary estimates of costs for processing fuels from several private power reactor proposals have been made available in Washington Document No. 403 which may be obtained by appropriately-clear people from the Technical Information Service, U. S. AEC, P. O. Box 1001, Oak Ridge, Tennessee.

Question 3. Will spent fuels from operational military reactors be available and what contractual arrangements would be made?

Answer 3. Although fuel processing requirements for a single military reactor are generally rather small, the large number of such reactors which are expected to be in operation ultimately will give a significant processing load. The exact size of this future load is not known to the AEC. The AEC considers it desirable that industry be given an opportunity to process these fuels. Proposals may include the furnishing of processing services for these fuels and this portion of the proposal may be considered by the AEC, jointly by the AEC and the Department of Defense, or singly by the Department of Defense.

Question 4. What are the quantities of AEC fuels that will be made available and for what period of time?

Answer 4. A summary of projected AEC fuel loads has been prepared, classified as Secret Restricted Data. It will be made available to appropriately-cleared persons upon written request.

Question 5. What is the story on inventory or use-charge during chemical processing.

Answer 5. The 4% inventory charge to the licensee will be in effect from the time the material is diverted from AEC channels until it is returned to AEC channels in suitable form and will therefore be in effect during processing. There will be no inventory charge for fuels from those private reactor projects in which the Commission waives the use-charge nor on Government fuels processed in the private facilities if the recovered special nuclear materials are returned in prescribed periods of time.

Question 6. What about responsibility for waste disposal from private processing plants?

Answer 6. The private processor should be completely responsible for the long-term storage of wastes on his plant site and any release of radioactive wastes from his plant. The AEC does not desire to accept any such wastes for permanent storage on AEC sites.

Question 7. Who will own the fission products in the wastes?

Answer 7. Ownership of the fission products from private power reactor fuels will be a matter of negotiation between the private power reactor owner and the

processor. Industry may want to consider the feasibility of recovering the valuable fission products for sales purposes in order to reflect a lower fuel processing cost. Any arrangements for transfer of ownership of such fission products would be a matter for negotiation. In any event the processor will be required to have a license to receive and to own this material.

Question 8. What will be the accountability procedures and requirements for private processors?

Answer 8. Sections 70.51 through 70.54 of Part 70, Title 10, Code of Federal Regulations, now provide only that each licensee shall keep records and make those records available to the Commission for inspection upon reasonable notice. No attempt will be made by the AEC to prescribe any internal accountability procedures or records for a licensee. However, it is planned by the AEC to institute a reporting and transfer system. By these means the AEC will be able to ensure that recipients, where required, have been properly licensed and will also obtain knowledge of the location of its material. Licensees will have a means of advising AEC of quantities of new material produced, burned, or otherwise disposed of in order that an appropriate adjustment of responsibility can be effected.

Question 9. What will be the patent rights?

Answer 9. Insofar as the private processor merely desires access to classified information, this access may be obtained under the regulations for "Access to Restricted Data," Part 25, Title 10, Code of Federal Regulations. Under proposed regulations now under review the Commission would waive (1) its rights in inventions or discoveries made or conceived as a result of access to Confidential-Restricted Data and (2) its rights, except to an irrevocable, royalty-free, nonexclusive license for governmental purposes, in inventions or discoveries made or conceived as a result of access to Secret Restricted Data. The permittee will waive claims for damages resulting from secrecy orders. If the use of AEC-owned facilities is involved, a patent provision to cover the use of such AEC-owned facilities would be incorporated. The appropriateness of a provision as respects the processing of AEC fuels would be dependent upon the nature and scope of financial and other arrangements involved in the processing of such fuels.

Question 10. In the case of nuclear reactors there is a definite procedure by which the Atomic Energy Commission resolves the nuclear safety problems. How is this to be handled for the case of chemical processing plants?

Answer 10. Before any private industry may legally engage in the chemical processing of special nuclear materials in their own facility, they must obtain a license from the AEC. Prior to issuance of such a license, the licensee must fulfill the requirements of AEC regulations.

Question 11. Will private industry be permitted to construct a processing plant and/or a fission product recovery plant on Commission sites?

Answer 11. The Commission has not considered this on a policy basis. If, however, the Commission authorized the location of a private processing plant on one of its sites, full responsibility for the long term storage of the wastes should still be retained by the private processor, subject to the regulations governing the individual AEC site. The construction of

(Continued on page 90)

FUELS REPROCESSING

(Continued from page 89)

a fission product recovery plant on an AEC site, such as Hanford, Savannah River, or the National Reactor Testing Station for the specific purpose of recovering fission products from Commission wastes is one that would deserve serious consideration by the Commission. If private industry desires to explore this further and would like to procure some high level wastes for developmental purposes, they should request of the AEC that samples or working size lots of our high level wastes be made available to them.

Question 12. What will be the various forms which the AEC will accept for returned special nuclear materials?

Answer 12. The Commission has established guaranteed prices to be paid licensees for the production of special nuclear materials delivered to the AEC before July 1, 1962. These prices will be made available to properly cleared persons. The complete specifications for these materials are classified and will be made available upon request to properly-cleared access permit holders. If the material received does not meet these specifications, such costs as are required to convert it to AEC specifications will be borne by the licensee.

Question 13. Does the Commission intend to pursue further the improvements of existing techniques and the development of new and more economical techniques for processing fuels from private and AEC reactors? Will the Commission finance any such work by the private processor?

Answer 13. The Commission recognizes that continued processing development work is required for AEC, military and private power reactor fuels. Our policy is to develop the technology for fuel processing so that industry can make the full-scale applications. The Commission may consider proposals by industry for development work on new processes and equipment.

Question 14. Will employees working for the private chemical processor require "L" or "Q" clearances?

Answer 14. The clearance requirement is dependent upon the type of classified information required by each individual in the performance of his work.

Additional questions can be answered by referring to the AEC's regulations which have been published in the Federal Register. Some of these have recently become effective and others will be promulgated soon in the Federal Register. Copies of both the effective and the draft regulations can be obtained by writing the Division of Civilian Application, U. S. Atomic Energy Commission, Washington 25, D. C.

The chemical processing of irradiated fuel from private power reactors is a tremendous challenge for industry and one that can best be met by industry. What is now a costly waste problem to the AEC may be an untapped source of profit to industry. The potentials of sterilizing food, promotion of chemical reactions, packaged power sources, medical and industrial tools are also in Pandora's box, but there are many more compartments to be explored.

ATOMIC ENERGY

(Continued from page 76)

OWNERSHIP AND REGULATIONS

Private ownership should be explored, a "practical value" determined, and uniform Federal-State regulations for safety and health be evolved.

FINANCIAL

Priorities for military vs. peaceful projects should be determined, charges for fuels for "demonstration" and other purposes be waived; free market for uranium should be an objective; AEC should sell radioisotopes at 20% of cost; guaranteed price schedule for production of specific materials be declassified.

PATENTS

Many issues should be reconsidered: AEC should announce is complete interpretation of patent provisions relating to private development and Government intentions not to file for its patent rights in foreign countries should be made known to inventors who might wish to file for such rights.

GOVERNMENT ORGANIZATION

The AEC should provide concentrated authority with responsibility for defining objectives of research & development. Other parts of Executive Branch should develop own organizations relating to atomic energy. Joint Committee should continue to serve the Congress, should make whatever adjustments and clarifications in the law as deemed necessary.

SECRECY

This aspect was reported on and discussed in detail in the February issue of *C.E.P.*, under "Opinion & Comment," page 43-F.

Damage was estimated in excess of $500,000 in the early-morning explosive ten-alarm fire that completely destroyed the offices and plant of Baltimore Aircoil Co.

Working night and day since the fire, the company has now arranged to begin production of its new line of cooling towers and evaporative condensers almost immediately, a completely modern new plant is expected to be on-stream in July of this year.

In the meantime, since the warehouse was not damaged, the company is filling some outstanding orders from its stock.

FUTURE MEETINGS and Symposia of the Institute

NEW ORLEANS

See pages 52 and 54 of this issue for the complete New Orleans Program.

MEETINGS — SYMPOSIA

■ PITTSBURGH, PA.

Sept. 9-12, 1956. Wm. Penn Hotel.

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Purdue U., Lafayette, Ind.

Distillation Computation Methods

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Operations Research

CHAIRMAN: George D. Creelman, M. A. Hanna Co., 1300 Leader Bldg., Cleveland 14, Ohio.

Case studies showing a wide variety of methods and techniques in applications of operations research in chemical engineering.

Explosions in Chemical Engineering

CHAIRMAN: G. H. Damon, 366 Ashland Ave., Pittsburgh 28, Pa.

Symposium on gas and dust explosions.

Unit Operations in Nuclear Engineering

CHAIRMAN: George Sege, General Electric Co., 2155 So. First St., San Jose, Calif.

How a basic training in chemical engineering fits into the work involved in the field of nuclear engineering, discussing results of unit operations researches done in conjunction with atomic energy projects.

General Papers

Deadline—May 11, 1956

■ ANNUAL—BOSTON, MASS.

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

MEETINGS — SYMPOSIA

Filtration

CHAIRMAN: F. M. Tiller, U. of Houston, Cullen Boulevard, Houston 4, Tex.

The flow of liquids through compressible media, with experimental and theoretical papers.

Low Temperature Techniques

CHAIRMAN: Clyde McKinley, Air Products Inc., Allentown, Pa.

The Sales Engineer in Chemical Engineering

CHAIRMEN: W. E. Hesler, Swenson Evaporator Co., 30 Church St., N.Y.C. 7; E. D. Kane, Cuno Eng. Corp., S. Vine St., Meriden, Conn.

Three Panels: "Introducing Mr. Chemical Sales Engineer," "Training the Chemical Sales Engineer," "Performance Yardstick of the Chemical Sales Engineer."

Afternoon at the Ichthyologists

General Session: "Obsolescence" of Chemical Engineers. Sunday P.M.: Round table discussion.

Deadline—August 9, 1956

■ WHITE SULPHUR SPRINGS, VA.

March 3-6, 1957.

■ PHILADELPHIA, PA.

March 11 through 15, 1957 (probable)

Nuclear Engineering Division Congress and Atomic Exposition, Philadelphia. "The Fuel Cycle."

UNSCHEDULED SYMPOSIA

Correspondence on proposed papers is invited.

Laboratory and Pilot Plant Techniques

CHAIRMAN: Thomas S. Leary, Calco Chemical Div., American Cyanamid Co., Bound Brook, N. J.

Centrifugation

CHAIRMAN: James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kan.

The theory and quantitative aspects of centrifugation.

Fluidization of Solids

CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Eng. Dept., Illinois Institute, 33rd Federal, Chicago 16, Ill.

Cost of Unit Operations

CHAIRMAN: John Happel, Chem. Eng. Dept., New York U., University Heights 53, N. Y.

Size Reduction

CHAIRMAN: Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.

Filtration & Centrifugation

CHAIRMAN: Horace Hinds, Jr., Corn Products Refining Co., Box 345, Argo, Ill.

Corrosion Resistant Alloy Materials of Construction

CHAIRMAN: G. Fred Our, Carbide and Carbon, Charleston, W. Va.

Dry Classification of Solids

CHAIRMAN: D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.

LOCAL SECTION Future Meetings

NEW JERSEY

1956 Lecture Series: "Factors Involved in Selecting Process Equipment."

Clinton School, Clinton Ave. and West 4th St., Plainfield, N. J.

March 27: "Fluids and Solids Transport Equipment," C. B. Hebenstreit, Bakelite Corp.

April 3: "Starting Up a New Plant," W. Ullrich, Lummus Co.

PHILADELPHIA—WILMINGTON

April 17, 1956.

University of Pennsylvania, Museum Auditorium, 33rd and Spruce Sts., Philadelphia.

"Economic Practices in the Chemical and Petroleum Industries."

Howard P. Kulp, Sun Oil, "Why Accounting." Lewis C. Knox, Catalytic Const., "The Plant Investment."

Allen E. Lawrence, DuPont, "Cost of Services." Howard R. Moody, Rohm & Haas, "Plant Operating Costs."

F. Faxon Ogden, Atlas Powder, "What Price the Product."

John C. Martin, Atlantic Refining, "Economic Analyses."

Karl Finsterbusch, Stone & Webster, "Financing the Plant."

TERRE HAUTE, IND.

April 21, 1956. Rose Polytechnic Institute.

1-day meeting on Bio-Engineering sponsored by the Terre Haute Section, A.I.Ch.E.

AUTHOR INFORMATION

Note: The Author Information column will appear quarterly in the January, April, July and October issues.

SAVE THOSE BACK ISSUES

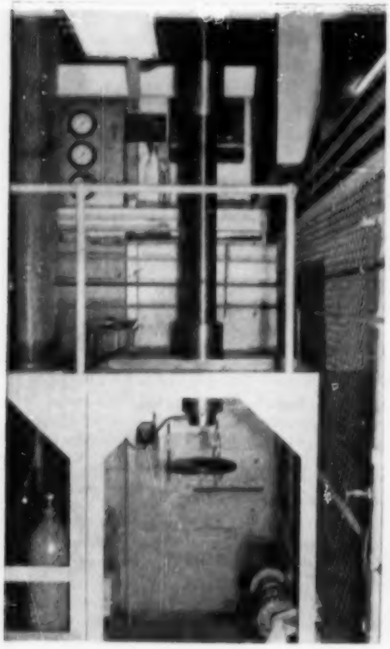
Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of Chemical Engineering Progress. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them. The issues which we need and for which we will pay 75 cents each are: April and May, 1947; January, 1949; and February, 1953.

All these issues were overprinted to a great extent, but because of features and other demands, single copy sales, etc., they were completely exhausted in a short time.

BALLISTIC PISTON—

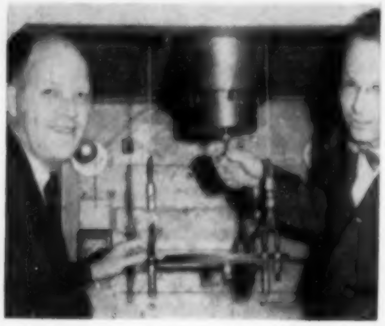
Basis for new chemical synthesis engine?

Initiated first by Russia and carried on in the U. S. by B. H. Sage and P. A. Longwell of California Institute of Technology, a revolutionary chemical reactor compresses gaseous reactants to 100,000 lb./sq.in., reaching temperatures as high as 10,000° F., and decompresses to atmospheric conditions, in time spans as short as ½ millisecond. Permits "freezing" of reactions under unusual equilibrium conditions. Work at Cal Tech being sponsored by Hercules Powder Co. and the Texas Co.



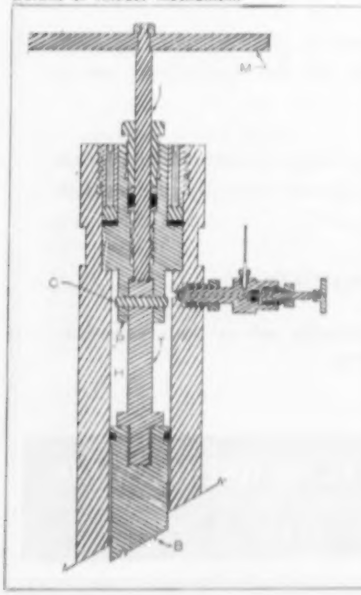
Overall view of the ballistic piston.

At the blackboard, Prof. Sage and P. A. Longwell discuss equipment modification.

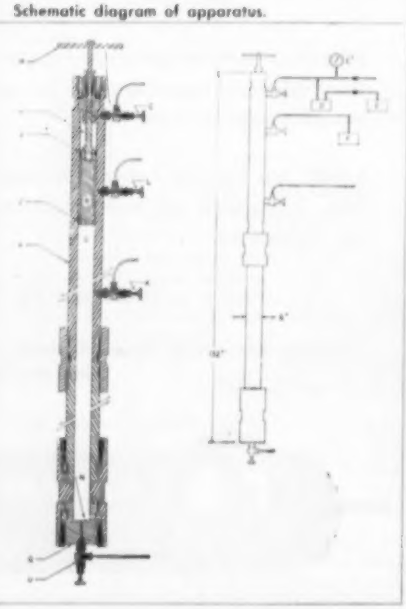


Sage and Longwell at bottom of ballistic piston setup, showing valve through which samples are removed.

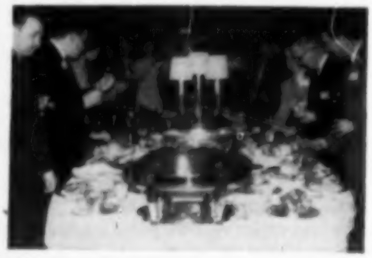
Details of release mechanism.



Schematic diagram of apparatus.



At the cocktail party: left to right, Mrs. Jack Tielrooy, Ted Weaver, Mrs. Weaver, and G. H. Hemmen.



And at the hors d'oeuvres table.

With entertainment.

Old Timer—John G. Dean, who became an Active Member of A.I.Ch.E. in 1908 and who is now 74 years old, with J. O. Adams, Dow.

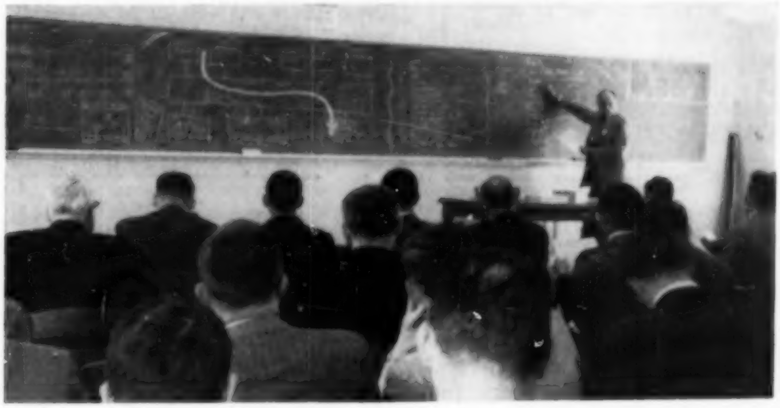
ROUND TABLE ON COMPUTERS

Helping the chemical engineer better plan maximum usage of available computer equipment, ranging from that used by his accounting department to the giants available on hourly rental.

at the

LOS ANGELES MEETING

At the amphitheater at UCLA, after visiting the Institute of Numerical Analysis Research, C.E.P.'s recorded round table discussion group made up of, left to right, Capt. T. J. Williams, U.S.A.F.; C. B. Tompkins and F. M. Hollander, UCLA; R. Curtis Johnson (moderator), Washington U.; Ascher Opler, Dow; and A. E. Hoerl, Du Pont.



At the Institute of Numerical Analysis Research, UCLA, chemical engineers hear lecture on how to set up problems for computer solution by Prof. T. H. Southard, associate research mathematician.

Some of those responsible for the success of the Los Angeles meeting are, left to right, front row: F. G. Sawyer, chairman, Public Relations Committee; T. Weaver, chairman, Technical Program Committee; D. R. Stern, co-chairman, Finance Committee; E. H. Lynch, co-chairman, Plant Trips Committee; and G. H. Hemmen, co-chairman, General Committee. Back row: D. K. Peterson, chairman, Arrangements Committee; C. E. Cuff, co-chairman, Registration Committee; J. W. Jensen, co-chairman, Registration Committee; E. R. Geib, chairman, Program Copy & Printing Committee; G. S. Peterson, chairman, Entertainment Committee; and B. M. Holt, co-chairman, General Committee.

INDUSTRIAL NEWS

Eleven Mexican cities are seeing Fischer & Porter's complete line of process instruments by means of a demonstration trailer now touring that country. □

A Symposium for Management on Industrial Applications of Analog Computers, sponsored by Midwest Research Institute in cooperation with technical societies, will be held at the Hotel Phillips, Kansas City, Mo., April 10-11. □

Construction will start immediately on a new chemical plant for the manufacture of Kralastic plastic materials by the Naugatuck Chemical division of U. S. Rubber. Located in the Scott's Bluff region of Baton Rouge, La., the new plant will cost more than $5 million, will more than double the company's capacity of the styrene, butadiene, acrylonitrile copolymer used mainly at present for the production of chemically resistant pipe, but expecting wide market expansion. □

Dorr-Oliver has announced its acquisition of Merco Centrifugal Co. Merco's line of centrifuges, centrifugal screens and strainers will add a new series of products to Dorr's large assortment of process equipment. □

Fifty papers on various aspects of industrial wastes and their treatment will be presented at the 11th Purdue Industrial Waste Conference, to be held at the University May 15, 16, and 17. ☐

The Garfield, Utah, cobalt refinery of Calera Mining Co., a subsidiary of Howe Sound Co., is now back in Calera's hands after a period of operation by its designer and builder, Chemical Construction Corp., a subsidiary of Cyanamid.

Chemico agreed to operate the plant early in 1954 to overcome certain technical and operating difficulties encountered by Calera after the plant's start-up in late 1952. The first plant to embody Chemico's patented processes for separating non-ferrous metals from their ore concentrates by means of chemistry rather than the more expensive smelting and refining methods, the refinery is now operating smoothly. ☐

The new 3-million-volt Van de Graaff accelerator manufactured by High Voltage Engineering Corp., Cambridge, Mass., is said to be the most powerful and versatile machine radiation source now commercially available. ☐

What's in a name? A great deal in the view of Brighton Copper Works, Cincinnati, which has just changed its name to Brighton Corp. Reason: the old name no longer describes the company's myriad activities in the fabrication of process equipment. Copper fabrication is now only a small part of the company's business of designing and fabricating tanks, kettles, fractionating towers, stills, evaporators, etc., for the process industries. ☐

World's first commercial plant for the production of U. S. Industrial Chemicals Co.'s new "U.S.I. Isosebacic" acid will go into construction at Tuscola, Ala. The acid, a special mixture of isomers of sebacic acid, is produced by a special U.S.I. process in which the basic raw materials are butadiene and sodium. U.S.I., a division of National Distillers Products, expects initial production of the acid to be some 10 million pounds per year. ☐

Continuing its policy of entering new and diversified fields, Borg-Warner Corp. has entered into an agreement for the acquisition of Primor Products, Inc., a manufacturer of refrigeration units for central air-conditioning systems. Primor will be operated as a division of Borg-Warner. ☐

A British subsidiary will be formed by Chemstrand for the manufacture of the company's acrylic fiber, Acrilan. ☐

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before April 15, 1956, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Bellan, Paul P., *Baton Rouge, La.*
Burkhardt, Donald B., *Newark, Del.*
Butler, Wendell T., *Columbus, Ohio*
Cocks, C. A., *Convent Station, N. J.*
Dahlstrom, Donald A., *Deerfield, Ill.*
Doolan, William H., *Akron, Ohio*
Gentry, William R., Jr., *Niagara Falls, N. Y.*
Guthrie, Jack A., *Marcus Hook, Pa.*
Hall, Myron C., *Clarendon Hills, Ill.*
Hardin, Donald C., Jr., *Stamford, Conn.*
Huckins, Harold A., Jr., *Larchmont, N. Y.*
Kachelhoffer, Fred G., *Portland, Ore.*
Kapnicky, James A., *Morgantown, W. Va.*
Lindahl, J. O. Philip, *Joliet, Ill.*
Luebbers, Ralph H., *Columbia, Mo.*
MacDonald, Bryce I., Jr., *Schenectady, N. Y.*
McClain, John R., *Nitro, W. Va.*
McCormick, Paul Y., *Newark, Del.*
McEachin, Eugene M., *Charleston, W. Va.*
Michel, Gilbert L., *Akron, Ohio*
Millar, Leonard L., *Pensacola, Fla.*
Nadler, Martin L., *Wilmington, Del.*
O'Neill, James A., Jr., *Chalmette, La.*
Pease, Richard W., *Peabody, Mass.*
Quinn, George F., *Falls Church, Va.*
Peters, Max S., *Urbana, Ill.*
Shearer, Robert W., *Ferguson, Mo.*
Shor, Arthur J., *Chicago, Ill.*
Smith, Frank W., *Pittsburgh, Pa.*
Smith, Verity C., *Dedham, Mass.*
Stone, Philip E., *Richmond, Va.*
Tate, Dan C., *Canton, N. C.*
Wright, Robert E., *Pensacola, Fla.*

Associate Member

Anderson, John E., *Grand Island, N. Y.*
Bates, Stanley I., *Midland, Mich.*
Bauer, Gregory A., *North Chicago, Ill.*
Bennethum, Earl W., *Reading, Pa.*
Bernstein, Joseph T., *Allentown, Pa.*
Bhatt, Mahendra, *Columbus, Ohio*
Bierbaum, Robert E., *Kingsport, Tenn.*
Boardman, Charles H., III, *Army Chemical Center, Md.*
Bradley, Clayton Thomas, Jr., *Wilmington, Del.*
Brandreth, Dale A., *Miquon, Pa.*
Brown, Vincent R., *Pasadena, Tex.*
Byron, James R., *Akron, Ohio*
Crowley, Duncan J., *Penns Grove, N. J.*
Davidson, Peter D., *New York, N. Y.*
Delocienda, Flavius, Jr., *Brooklyn, N. Y.*
Donohue, Walter A., *West Orange, N. J.*
Drake, George M., Jr., *Knoxville, Tenn.*
Dunlop, H. A., *Cincinnati, Ohio*
Dvoracek, Louis M., *Wilmington, Calif.*
Ehrenreich, Richard, *Pittsburgh, Pa.*
Etani, Kenzi, *Cambridge, Mass.*
Feder, Herbert, *Niagara Falls, N. Y.*
Fox, F. E., Jr., *Rochester, N. Y.*
Frohman, L. Todd, *Bronxville, N. Y.*
Gaddis, Vaughn E., *St. Louis, Mo.*
Garner, James W., *Borger, Tex.*
Gaskill, Herbert L., *Seattle, Wash.*
George, James R., *Wilmington, Del.*
Giblin, John F., *Pensacola, Fla.*
Gibson, Lowell C., *Whiting, Ind.*
Green, Leon, *Philadelphia, Pa.*
Grins, Margers, *Columbus, Ohio*
Harms, Verne E., *Mandan, N. D.*
Hebbel, George T., *Belvidere, N. J.*
Henderson, Craig, *North Chicago, Ill.*
Hepp, Peter S., *Springfield, Pa.*
Hoffman, Bernard, *Knoxville, Tenn.*
Houghton, George Lewis, *Media, Pa.*
Hungerford, Fulton, *Corpus Christi, Tex.*
Kawahata, Masayuki, *University Park, Pa.*
Klee, Richard F., *Buffalo, N. Y.*
La Borde, H. J., *La Marque, Tex.*
Lackey, Daryl L., *University City, Mo.*
Lapin, Abraham, *Allentown, Pa.*
Laundrie, James F., *Ellsworth A.F.B., S. D.*
Leverett, James R., Jr., *Luckey, Ohio*
Logomasini, James C., *Edgewood, Md.*
Majani, Bernard, *Fulton, N. Y.*
Malinoski, Thomas J., *Stamford, Conn.*
McAvoy, B. F., Jr., *Orange, Tex.*
McCandless, Henry A., *El Dorado, Ark.*
McCorney, John M., *Silvis, Ill.*
McDermott, Melville C., *Louisville, Ky.*
Merken, Henry, *Lynn, Mass.*
Nicholson, William J., *North Augusta, S. C.*
Nakay, R., *Cincinnati, Ohio*
Patton, James L., *Wilmington, Del.*
Pitts, Homer D., *Cushing, Okla.*
Richards, Vincent L., *Jersey City, N. J.*
Rivers, Ernest L., *Port Arthur, Tex.*
Rogers, Joe Y., Jr., *Pampa, Tex.*
Rohn, William J., *Cicero, Ill.*
Roquemore, William K., *Baytown, Tex.*
Rossi, John F., *Wilmington, Del.*
Satas, Donatas, *Chicago, Ill.*
Schmid, Walter E., *Tonawanda, N. Y.*
Scully, Dennis A., *Wilmington, Del.*
Singleton, O. R., Jr., *Richmond, Va.*
Spater, Stuart S., *New Castle, Del.*
Stein, Ralph, *Columbus, Ohio*
Steinmetz, James M., *Midland, Mich.*
Steward, Robert E., *Hopewell, Va.*
Stumpe, J. Jerome, *Florence, Ala.*
Suval, Marvin L., *Kenmore, N. Y.*
Szold, Robert E., *Arthur, Ill.*
Vaughn, John M., *Crestview, Fla.*
Wallack, Marvin H., *Framingham, Mass.*
Westkoemper, L. E., *Pasadena, Tex.*
Whittington, E. L., Jr., *Houston, Tex.*
Zarroli, Camillo A., *Lewistown, Pa.*

Affiliate

Goltz, G. E., *Durban North, South Africa*

INDUSTRIAL RECRUITING IN COLLEGES —Ethical or Unethical

Subcommittee of Professional Development Committee of A.I.Ch.E. investigates charges of unethical recruiting practices.

Faced with some indications of unethical recruiting practices in colleges on the part of the chemical industry, the Professional Development Committee appointed a special subcommittee at the recent Annual meeting in Detroit to investigate.* Conclusion: no serious problem of this nature exists, further investigation is unnecessary.

Using a questionnaire method, the subcommittee received answers from 69 colleges. Of these, 14 replies gave examples of unethical or objectionable recruiting practices. The great majority of replies, however, were complimentary to industry, indicating good relations and practices experienced with most recruiters. In addition, the colleges indicated that if objectionable tactics were used and came to their attention, stern measures would be taken to insure their discontinuance. In the face of these facts it was clear that no serious problem exists.

* Members: R. A. Ghelardi, M. M. Striplin, Jr., G. C. Williams, and H. R. Paxton.

Objectionable Tactics

Among the objectionable tactics mentioned were:

1) Use of high pressure to force a decision—6 complaints.
   - a—Unrealistic dealine dates.
   - b—Short time for decision.
   - c—Increasing offer after student already has another position.

2) Criticism of other potential employers—2.

3) Misrepresentation of:
   - a—Work assignments—2.
   - b—Job location—2.
   - c—Amount of travel—2.
   - d—Promotional opportunities—1.
   - e—Duration of lab. work—2.
   - f—Salary—1.
   - g—Training program—2.
   - h—Living conditions at plant—1.

4) Use of unofficial procedures to contact students, i.e., by-passing placement office.

5) Hiring students in excess of requirements to insure a full staff—2.

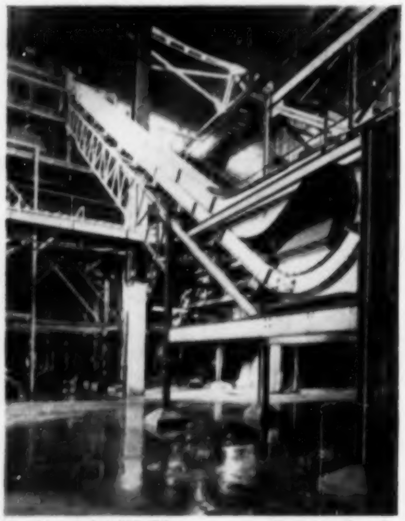
6) Stopping a fellowship if not shown best students.

Complete information was not obtained concerning the type of process industries involved in all of the above complaints but the following were mentioned: Steel, plastics, nuclear, petroleum, aeronautics, heavy chemicals, paints, pharmaceutical, rubber and insurance. Complete information was not obtained as to the sizes of the companies involved, but in general they seemed to fall into the 2,000 employees to 5,000 employees group.

Two special bulletins of the latest collection of Karl Ziegler patent literature from Belgium, Italy and Germany on ethylene polymerization catalysts and low-pressure polymerization of propylene, are now available from Research Information Service, 53 Nassau St., New York. □

First colloidal graphite plant to be constructed in The Netherlands will be built by Acheson Industries, Inc. □

Responsibility for the design and development of a military nuclear reactor plant for production of electricity and for space heating has been assigned to Argonne National Laboratory, Pioneer Service and Engineering Co., Chicago, has been chosen to work on the design of the low-power heterogeneous boiling reactor as well as the associated plant. □



people

R. F. Cole assumes the duties of chief engineer of Newport Industries, Inc., N. Y. He received his B.S. degree in chemical engineering from Massachusetts Institute of Technology in 1938. Mr. Cole has been with Newport since 1939, and is the chairman of the Pensacola Chemical Engineering Club.

"To further streamline operations," Girdler Co. make· ·rganization changes in gas processes div.: **R. M. Reed** to technical advisor to executive vice-president; **C. J. Randolph** to asst. chief engineer, process section; and **F. A. Hilinski** to asst. chief engineer, project section.

Daniel D. Perlmutter is a new member of the chemicals development division of Esso Research and Engineering. He is a graduate of New York and Yale Universities. **John L. Bryan, Jr.,** also joins the staff of Esso's chemicals development division. He is a graduate of Mississippi State College and the U. of Wisconsin.

Michigan Sewage and Industrial Waste Assoc. appoints **G. A. McBride** vice-president. McBride is district sales engineer with Infilco, Inc., manufacturers of equipment for water and waste treatment.

James F. Roe promoted to manager of the Florida operations of the phosphate chemicals div. of International Minerals and Chemicals Corp.

U. S. Bureau of Mines, Reno, Nevada, names **Ray H. Jebens** project supervisor, rare earth research projects, with emphasis on rare metals technology.

Clifford B. Armstrong, Jr., appointed Michigan representative of Hungerford & Terry, manufacturers of water treating plants.

Dow Chemical appoints **Robert E. Reinker** its manager of the Riverside Plant at Pevely, Mo.

Atlas Powder announces the appointment of **Carl D. Pratt** as technical assistant to the director of product development.

R. S. Conly becomes assistant general foreman of the light ends department, process division, for Humble Oil & Refining at Baytown, Texas. In the technical service division, **C. H. Marshall** becomes section head to direct activities of the solvents group.

Harry J. Karakas is made manager, process equipment division, Rodney Hunt Machine Co., Orange, Mass. He is responsible for application, development, engineering and sales activities of the division.

Edward J. Fradkin joins the Scientific Design Co. of N. Y. after seven years with Chemical Construction Corp. He is a graduate of M.I.T. and the City College of New York.

Robert S. Aries has been elected a fellow of the N. Y. Academy of Sciences.

Charles J. Marsel, chemical engineer, is elected president of American Rocket Society's N. Y. Chapter. He is an associate professor at N.Y.U. and conducts research on guided missiles and rocket fuels under Army, Navy, and Air Force sponsorship in the N.Y.U. Engineering Research Division.

G. A. Webb becomes director of engineering at Mellon Institute.

Elwood I. Clapp, Jr., advanced to senior economic analyst for industrial chemicals div., American Cyanamid.

Professor **Mars G. Fontana** of Ohio State U. has been selected the 1956 recipient of the Speller Award by the National Association of Corrosion Engineers. Presentation will be made during the national meeting, N. Y., in March.

Henry J. Ogorzaly appointed by Esso Research and Engineering Co. to follow its program of nuclear activities affecting chemical and petroleum processes and products quality. Ogorzaly is also an assistant director of the company's petroleum development div.

Martin A. Elliott, research professor at Illinois Institute of Technology, is appointed director of the Institute of Gas Technology. Dr. Elliott, a gas engineer, has been a member of the staff of I.I.T. since 1952.

people

Dr. William von Fischer has been appointed coordinator of research and development for the Glidden Co., Cleveland, Ohio. During the past eight years he headed the department of chemistry and chemical engineering at Case Institute of Technology and will assume his new position at the close of the present academic year.

Bruce H. Strain promoted to associate director of Procter & Gamble's research and development.

Earle F. Young, Jr., is appointed process engineer—chemical engineering services, technical services division, Jones & Laughlin Steel Corp.

Wilburn J. Butler to works manager of Diamond Alkali's Houston, Texas plant.

Bertram C. Raynes to head department of chemical engineering of Horizons, Inc., in Cleveland, a government and industrial research organization.

Joseph E. Ross named leader of tire yarn research at American Viscose, Marcus Hook, Pa.

John S. Rearick elected vice-president by C. W. Nofsinger Co., Kansas City. Rearick became manager of engineering of that company in 1954, after 16 years of experience with M. W. Kellogg in the development of petroleum and chemical processes.

Esso Research and Engineering's N. J. laboratories div. adds **Alan A. Schetelich** to its staff.

W. Alec Jordan, formerly editor-in-chief of *Chemical Week*, long-time expert in technical service and chemical sales management, has entered practice as a chemical business consultant with offices at 270 Park Avenue, New York. Jordan will specialize in market development, product promotion and related chemical problems.

R. P. Genereaux, Du Pont, named A.I.Ch.E. representative on The American Standards Association's planning committee on standardization in the field of nuclear energy. **J. C. Lawrence** is A.I.Ch.E.'s alternate on the 25-member committee which represents industrial and Governmental organizations in the field.

Ju Chin Chu, chemical engineering staff of Polytechnic Institute of Brooklyn, is named a consultant with the U. S. Dept. of Agriculture. He will serve on the Southern Utilization Research Branch, Agricultural Research Service. Professor Chu is also a consultant to Argonne National Laboratory and Curtiss-Wright Corp.

Leslie H. Landrum is appointed director of process development for the Spencer Chemical Co., Kansas City, Mo. Before this assignment, he represented Union Electric of Mo. in the nuclear power group, and was chief process engineer for American Cyanamid in Idaho Falls, Idaho.

Wallace J. Murray has retired after thirty-five years with Arthur D. Little, Inc., Cambridge, Mass. Dr. Murray will continue to serve the company as a consultant.

Clayton Carter becomes plant manager of the new Murphy Corp.-Michigan Chemical Corp. bromine plant under construction at El Dorado, Ark.

Peter D. Moskovits to staff of the technical library of Esso Research and Engineering, Linden, N. J.

Carl M. Cooper, technical director of Vulcan engineering division, Vulcan Copper & Supply Co. during the past year and professor of chemical engineering on leave from Michigan State U., has returned to full time teaching and consulting work at East Lansing.

Norbert S. Mason to B. F. Goodrich Co. research center, Brecksville, O.

Victor Mills named to head the newly-established exploratory development dept. of Procter & Gamble.

On March 1, **L. F. Davis** became plant manager for Shawinigan Resins Corp.'s new plant at Trenton, Mich.

George F. Klein, Jr., is made vice president in charge of engineering and elected to the Board of Directors of Catalytic Construction Co., Philadelphia. He will be in charge of all engineering for the firm, currently involving projects with a construction cost of more than $50,000,000. During his career, Mr. Klein has been an engineering executive with Spencer Chemical, National Aniline, and Hercules Powder.

people

Donald Q. Kern announces formation of D. Q. Kern Associates, Cleveland, Ohio. Specializing in thermal process technology, the firm consists of five associates from the fields of distillation, high pressure techniques, nuclear engineering, heat transfer and thermodynamics, and a supporting staff of 50 chemical, mechanical and structural engineers. Branch offices are located in New York and Washington, D. C.

Richard N. Augustson has taken leave of absence from Monsanto in St. Louis for a two-year assignment with Monsanto Chemicals Ltd. in England. He is working there on economic and progress studies in the development department.

Carl C. Monrad is appointed to the subcommittee on aircraft fuels, National Advisory Committee for Aeronautics, Pittsburgh. Prof. Monrad is head of chemical engineering at Carnegie Tech.

Shen Wu Wan is named director of research and development of Chemical Construction Corp., N. Y.

Lawrence N. Canjar given the Carnegie Teaching Award in chemical engineering. Each year Carnegie Institute of Technology selects four of its teachers who are most outstanding as measured by their influence upon the teaching of others and upon Carnegie's educational objectives.

A. P. Moss appointed industrial chemicals production manager of Carbide and Carbon Chemicals Co. in N. Y.

Leslie H. Schnurstein is production superintendent, and **Lawrence P. Hallahan** is plant engineer, at Hooker Electrochemical's new chlorine-caustic plant at North Vancouver, B. C.

William J. Hutchinson named a director of American Potash & Chemical.

Richard L. Demmerle, formerly a consultant with Booz, Allen & Hamilton, has joined Batten, Barton, Durstine & Osborn, Inc., as an account executive on the E. I. du Pont de Nemours account. He was also formerly executive editor of *Chemical Week* and associate editor of *Chemical & Engineering News*.

Richard E. Chaddock is appointed director of development for the Virginia Cellulose Dept. of Hercules Powder. The position will entail technical aid to present markets, expansion of markets and introduction of new chemical materials.

Irving Saslaw appointed project leader in the research department of the Walter Baker Div., General Foods Corp., Dorchester, Mass.

Colonel J. H. Rothschild is named Commanding Officer, Chemical Corps Research and Development Command, Washington, D. C. He was formerly president of the Chemical Corps Board, Army Chemical Center, Maryland.

Arthur D. Little, Inc., Cambridge, Mass., has added **Kymus Ginwala** to its process development group. Ginwala received his M.S. degree in 1954 from M.I.T.

Robert A. Bondurant becomes general service superintendent at the South Charleston, West Va. plant of Food Machinery and Chemical Corp.'s Chlor-Alkali Division. In New York, **James G. Bronson** becomes staff assistant to the president of the Chlor-Alkali Division.

Raymond Stevens, is the new president of Arthur D. Little, Cambridge, succeeding **Earl P. Stevenson,** who becomes chairman of the board. Stevens has also been selected the 1956 recipient of the Gold Medal of the American Institute of Chemists. The award, in recognition of work toward the wider understanding of the management and operation of industrial research, will be presented in Boston in May.

Corn Products Refining Co., Argo, Illinois, has made two changes in the staff of its chemical division. **Robert H. Rogge** is appointed director of engineering and **John E. Dlouhy** succeeds him as assistant director of engineering in charge of development and the pilot plant.

Donald W. Beery becomes manager of the low temperature and synthetic fuels department, chemical plants division, Blaw-Knox Co., Pittsburgh. With the firm since 1948, Beery has recently made a study of operating procedures and techniques in Europe.

the chemical engineer in MARKETING

George L. Ogdin, Jr., is the new general sales manager of the Fulton Sylphon Div., Robertshaw-Fulton Controls Co., in Knoxville, Tenn. Ogdin, with the firm since 1940, held various positions at Knoxville until 1944, when he was transferred to the Detroit sales office. He returned to Knoxville in 1953, becoming assistant general sales manager.

Paul N. Strobell has been chosen by Alco Products, Schenectady, N. Y., marketing manager for atomic energy products. This appointment marks an expansion of the company's atomic energy activity, and will involve sales of reactors, power plants, and other nuclear products.

Du Pont's Petroleum Chemicals Division has appointed **J. J. Mikita,** formerly director of the petroleum laboratory, as sales manager of its additives sales group, with headquarters in Wilmington, Del.

E. L. Meadows is promoted to supervisor, marketing information services, for Carbide and Carbon in N. Y. Mr. Meadows will be responsible for organizing and expanding a marketing information center to keep up to date all technical and marketing information for sales purposes.

Richard M. Sibley, new sales engineer of Dorr-Oliver's Eastern filtration div. at Stamford, Conn.

Norman E. Hathaway is made coordinator of marketing for Oronite Chemical Co. in San Francisco. Hathaway occupies a new position, created in conjunction with a marketing department reorganization brought about by the firm's growth.

Clifford S. Hancock, manager of calcium carbonate sales at Diamond Alkali, Cleveland, will assume the added responsibility for sale of all Diamond silicate chemicals, excepting detergent silicates. Hancock joined the company in 1925 and became manager of calcium carbonate sales in 1948.

A. J. Weith is elevated to sales manager of American Cyanamid's petrochemicals department in N. Y. Receiving his Ph.D. from Duke in 1946, Weith joined Cyanamid as a research chemist in 1947 and after two years was transferred to the industrial chemicals division. In 1954 he was made assistant sales manager of petrochemicals.

E. J. Bock, Monsanto Chemical Co., is named associate director of marketing for the inorganic chemicals division, St. Louis. Since 1948 he has been plant manager of the elemental phosphorous plant in Tennessee.

Necrology

Ernst A. Hauser, 59, professor of chemical engineering at Massachusetts Institute of Technology, and an internationally-known authority on colloid science. Dr. Hauser authored numerous books and papers on colloids and allied chemical fields, received citations and honors from scientific societies throughout the world.

George Oenslager, 82, former chief chemist of the B. F. Goodrich Co., and a discoverer of organic accelerators to speed the vulcanization of tires. Credited with introducing carbon black as a cheaper antiabrasive, honored by the American Chemical Society and the Society of the Chemical Industry for his work.

W. M. Reed, 63, founder and chairman of the board of the American Air Filter Co., Inc., Louisville, Kentucky.

Guerin Todd, Sr., 60, of Hanson-Van Winkle-Munning Co., a widely known engineer in the electroplating equipment field.

William T. Haebler, industrialist who had served as vice president, treasurer, and director of Van Ameringen-Haebler, Inc.

News of the Field
FROM LOCAL SECTIONS

SYNTHESIS GAS GENERATION AND AMMONIA SYNTHESIS ANALYZED

Tulsa Section hears detailed analysis of partial oxidation processes, now in use, at its January meeting.

There are now four plants in the U.S. employing partial oxidation for generation of hydrogen from natural gas: Spencer Chemical's Vicksburg, Miss., plant, Cooperative Farm Chemicals Association's Lawrence, Kans., installation, John Deere's Pryor, Okla., plant, and Grace Chemical's Memphis, Tenn., facilities. G. S. Merritt of Foster Wheeler's chemical plants department, the speaker at the meeting, has been associated with design and start-up of all four plants, discussed two processes: the Texaco partial combustion process and the Casale ammonia synthesis process.

In the Texaco process natural gas and oxygen are automatically proportioned to the gas generators where reaction takes place at above 2500° F. Controls are complex but experience has been satisfactory. Design calls for 6 generators for a 250 ton/day ammonia plant. Burners have run from 3000 to 4000 hours between inspections although shorter periods were originally recommended. Following gas generation comes a quench step, the shift reaction step, removal of CO_2 by ethanolamine and caustic scrub, and removal of CO, small amounts of methane, and traces of CO_2 by nitrogen wash. In practice the nitrogen wash has proven its worth. Merritt cited a case where the nitrogen wash prevented CO_2 from getting on the catalyst by removing the CO_2 when the amine scrubber came down.

In the high-pressure (9000 lb./sq.in.) Casale synthesis an educator is used to circulate unreacted gases in the synthesis loop, and water cooling is employed to condense the ammonia. This is in contrast to low-pressure processes which require ammonia refrigeration for condensation.

In comparing partial oxidation with high-pressure steam-methane reforming, Merritt pointed out that the choice depends to a great extent upon local conditions, i.e., cost of power and natural gas.

In discussing production of oxygen for partial combustion methods, Merritt noted advantages in pumping oxygen to desired pressure as a liquid, avoiding the mechanical problems of oxygen compressors.

ELECTRONIC COMPUTERS FEATURED AT DELAWARE SYMPOSIUM

Philadelphia-Wilmington Section joins Delaware Section of ACS in Eighth Annual Delaware Chemcal Symposium.

In the chemical engineering session of the annual chemical meeting, held this year at the University of Delaware in February, one of the featured subjects was the contribution of modern electronic computers to advances in chemical engineering research.

Speaking on high temperature reactions, W. F. Jaep of Du Pont's Engineering department, pointed out how the extremely rapid computing speeds of "Univac," one of the better known of the new "electronic brains," makes it possible to select promising compounds for possible commercial development based upon the solution of a number of mathematical equations. By using the computer for this work, much costly experimental work can be avoided.

The use of another "giant brain," IBM's 701, in the solving of chemical engineering problems was described by R. E. Gee, Du Pont polychemicals department, in connection with work in the field of molten plastics.

Chairmanned by A. B. Metzner (assoc. Chmn., J. W. Hoopes, Jr.), the chemical engineering session also heard E. F. Leonard & P. F. Haggerty discuss frequency response of heat exchangers, K. Wohl & E. T. Child analyze free radical decay mechanisms in flames, how cost estimates help guide chemical research from J. C. Tallman, and a comparison of physical separation processes by V. Verplanck.

(*Continued on page* 112)

(*Continued from page* 110)

SCIENCE IS INTERNATIONAL WHITMAN TELLS LOCAL SECTIONS

The success of the Geneva Conference on Atomic Energy suggests that world-wide cooperation is indeed possible when an atmosphere of mutual respect and understanding exists, president Walt Whitman told members of the **Boston Section** (*A. S. Collins*) and **Northern California Section** (*J. E. Walker*). The natural affinity which scientists feel for one another was maintained at Geneva by excluding political interferences and propaganda and avoiding dominance by any one nation. In fact, Whitman emphasized, as conference secretary general he himself had to forget he was American and function as a true citizen of the world.

Still on the international scene, but in a more competitive spirit, the **South Texas Section** (*J. H. Presnell*) heard E. B. Barnes of Dow analyze the resurging German chemical industry at its December meeting. Main conclusion: While the U. S. chemical industry is now far ahead of the Germans in many respects, the Germans have tremendous know-how and the German chemical industry will always prove tough competition. Today, one of the most serious German shortcomings is lack of raw materials.

New Section—Attendance

A new section, the **Coastal Bend (Texas) Section** (*O. L. Culberson*) with headquarters in Corpus Christi, was formally welcomed into the Institute on February 7. With 71 members at present, the new section has J. J. Maurer as chmn., J. B. Dahms as chmn.-elect, O. L. Culberson as secretary, J. R. McKlveen as treasurer.

At its January meeting, the **South Texas Section** (*G. B. Gibbs*) made an interesting survey of its attendance by company, giving particular credit to the Texas Univ. and Alcoa engineers for travelling so far.

Monsanto	17	Maint. Engr.	2
Humble	12	Alcoa	2
Amoco	9	Petro-Tex	2
Diamond	6	C & EN	1
Hedrick	6	Lummus	1
Eastern States	5	Consultants	1
Du Pont	5	Ethyl	1
Refiner	4	Delhi	1
Carbide	3	Mathieson	1
Fluor	3	Jefferson	1
U-Tex	2	Delta	1
Rice	2	Texaco	1
IBM	2	Processors, Inc.	1

(*Continued on page* 114)

A.I.Ch.E. **News of the Field**
FROM LOCAL SECTIONS

(*Continued from page* 112)

Future Engineers—Where From?

To stimulate the interest of high school students in science, particularly in chemical engineering, the **Alton-Wood River Section** (*M. W. Stacy*) is sponsoring an essay contest on "What The Chemical Profession Offers Me as a Career." Limited to seniors in 7 local high schools, the contest has a $100 savings bond as first prize, $25 bonds as prizes for the best essay in the remaining six schools. The prizes were made possible by 9 process companies in the area.

Attacking the same problem, the **Western New York Section** has come up with its own plan to interest high school seniors in chemical engineering. It will arrange for speakers and counsellors to present engineering's picture on the high school's Career Day, is inviting any and all high school students to join it in its field trips.

On another tack, the **Student Chapter at Clemson** decided to learn about the world of engineering outside by inviting back 7 of its recent graduates in the field to tell present students just what a graduate encounters on his first industrial job, what the graduate thinks of his undergraduate education today. Plans are being made to make this an annual affair.

Plastics—Automobiles

Plastics were the subject at recent meetings of the **St. Louis** (*R. York*) and **New Haven Sections.** At St. Louis, R. H. Kittner, Mobay Chemical, described the formulation and application of polyurethanes as elastic and rigid forms, surface coatings, adhesives, elastomers, and plastics, illustrated his detailed talk with a motion picture on urethane foam manufacture. In New Haven it was A. A Miller, General Electric, presenting the major characteristics and sources of ionizing radiation, some principles of radiation chemistry, as background for the discussion of radiation's effect on polymers. Emphasizing polyethylene, Miller discussed physical and chemical changes due to ionizing radiation, radiation stability, crosslinking, and degradation.

Chemicals in automobiles held the spotlight at the December meeting of the **Rochester Section** (*J. E. Millard*) where G. R. Norman and W. C. Brandow, Lubrizol Corp., stressed the need

(*Continued on page* 121)

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

SITUATIONS OPEN

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 20¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $17 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

ENGINEER

National chemical manufacturer requires a man with experience in chemical plant operation or with refrigeration and power plant experience to assume position of plant superintendent after approximately one year of training. Prefer young man 25 to 35 years of age with an engineering degree; however, men with less education will be considered. Should have proven record of successful supervision and management.

Please submit complete résumé with snap shot including education, experience and salary requirements. All replies will be treated with strict confidence. Box 27-3.

CHEMICAL ENGINEER OR CHEMIST

Minimum four years' production experience for key position as production superintendent of new plastics plant. Working knowledge of plant maintenance required.

Thompson Chemical Company
90 Mendon Avenue
Pawtucket, Rhode Island

SOUTHWEST

Established chemical manufacturer has responsible positions available in Development Laboratory adjoining plant in Southwest. This Laboratory is now undertaking major program of plant improvement. Positions available include—

1 CHEMICAL ENGINEER (Ph.D. or equivalent) to assume responsibility for new plant projects.

2 PHYSICAL CHEMIST (Ph.D. or equivalent) to lead fundamental laboratory investigations.

3 ANALYTICAL CHEMIST (M.S. or equivalent) for technical service work.

Please reply with résumé and salary requirements to Box 9-3. All replies will be held in confidence.

ACADEMIC POSITION—Chemical engineer, age forty or younger, graduate degree, active member A.I.Ch.E., to fill vacancy in department of midwestern university for fall 1956. Research and consulting encouraged. Rank and salary depending on qualifications. Give full particulars, including personal data, training, experience, references. State salary requirements. Include recent snapshot. Box 13-3.

WANTED CHEMICAL ENGINEER with experience in contact sulphuric acid manufacturing for Michigan area, under thirty years of age; send photo, résumé of experience and salary expected. Box 7-3.

CHEMICAL ENGINEER—Recent graduate to train for position as thermal design engineer with established manufacturer of process heat transfer equipment. Position will entail thermal and mechanical design of equipment. For Elyria, Ohio office. Write, giving personal data to: Chief Engineer, Brown Fintube Company, Elyria, Ohio.

SITUATIONS WANTED

A.I.Ch.E. Members

CHEMICAL ENGINEERS—Eight years' experience process development, general pilot plant, catalyst studies. Strong in human relations, enthusiasm, writing ability. Supervisory experience. Ambitious to move into management level. Box 10-3.

RESEARCH-DEVELOPMENT ENGINEER—M.S.Ch.E. 1949. Six years' experience in process and equipment development; project engineering; technical report writing; supervision. Publications. Desire responsible position in process or product development. Present salary $7,600. Age 27, family, veteran. Box 11-3.

CHEMICAL ENGINEER—Age 31, family. Four years' experience process development, fats and oils. M.S.Ch.E., summer 1956. Seeking experience leading to responsible position in process design or development. Foreign or domestic. Box 12-3.

DIRECTOR OF RESEARCH OR ADMINISTRATIVE ASSISTANT position desired. Broad experience in all phases of manufacturing industry. Capable coordinator, technical representative, and public speaker. Can supply excellent references. Ph.D. in Chemical Engineering. Age 38. Box 14-3.

CHEMICAL ENGINEER—M.S. Age 38, fifteen years' experience in production, process, design and supervision. Capable, effective and cost-conscious. Desire greater managerial or technical responsibility. Minimum salary $15,000. Box 15-3.

PRODUCTION ENGINEER—B.S.Ch.E., 1942. Broad experience in pharmaceutical industry including fermentation. Two years' pilot plant, eight years' production supervision, new plant start-up, economics, process improvement, and safety. Two years' development engineer. Desires position offering opportunity in production, engineering, or management. Box 16-3.

TECHNICAL SUPERVISOR—Chief engineer or equivalent to organize or assume process development, complete plant design and project responsibilities. From research through construction. Eighteen years' industrial chemical engineering background. Please outline situation. Box 17-3.

CHEMICAL ENGINEER—B.Ch.E., 1951. Age 26. Three years' experience process improvement and trouble shooting, production supervision, quality control. Graduate work in Applied Statistics. Married, veteran. Desires responsible and demanding position. Box 18-3.

CHEMICAL ENGINEERING graduate student desires position in research, process development, or process instrumentation. Prefer location near school where graduate program could be continued part-time. B.S.Ch.E., 1952; anticipate M.S. June 1956. Age 25; married. Box 19-3.

CHEMICAL ENGINEER—M.S. Three years' diversified experience with major chemical plastics company. Process development, design, report writing, cost estimates—styrene, vinyls, organics. Shift supervisor. Honor societies, patents, papers. Desire position with future within 50 miles New York City. Box 20-3.

CHEMICAL ENGINEER—B.Ch.E., 1953. Age 33. Pilot plant experience in development of synthetic organics, vitamins and steroids involving scale-up from lab to production. Desire position in process engineering. Graduate work, veteran, married. Box 21-3.

SALES MANAGEMENT—Ten years' successful sales engineering and instrument application to the chemical industry. Other experience five years' production supervision of petrochemicals. Desire sales management work for company ending equipment to chemical, nuclear, or metallurgical industries. Box 22-3.

CHEMICAL ENGINEER—B.S. in Ch.E., 1951, age 34. Experience in pilot plant supervision, process engineering in biologicals and munitions. Prefer North East area. Desire work in production or development. Married, veteran. Box 23-3.

CHEMICAL ENGINEER—M.S.Ch.E., P.E., age 34. Eight years' experience in organic pilot plant and inorganic plant operations. Presently supervisory level. Desires responsible position in production or development. Box 24-3.

CHEMICAL ENGINEER interested in applied mathematics and machine computation. Sc.D.; age 24; married. Twenty-one months' experience in pilot plants, design groups currently employed. Small company in Midwest preferred. Box 25-3.

CHEMICAL ENGINEER—Ten years' experience in development research and production in fine chemicals. Tau Beta Pi Mu Epsilon. Have mathematical mind and interest in economics of industry. Interested in progressively managed company. Box 26-3.

A.I.Ch.E.

News of the Field

FROM LOCAL SECTIONS

(*Continued from page* 114)

for lubrication additives in present day engines and gears, and explained the chemical nature of these additives. It was autos again at the **Southern California Section's** meeting in December. P. Kyropoulis, Cal Tech, discussed the increase in auto horsepower and what the petroleum industry has done to keep up with it. Piston engine horsepower is expected to increase to about 450-500 h.p., and then turbine engines will probably take over. There are problems in both types of engine, but one fact is certain: economy in fuel use must be stressed. Our engines are not as efficient as they could be, and a very small improvement in the efficiency of all the automotive engines in the country could provide enough fuel to run all the railroads and central power stations.

Turning to gas turbines themselves, L. Eltinge, Standard Oil (Indiana), told the January meeting of the **El Dorado Section** (*D. S. Thomas*) that the two-shaft turbine seems to have the inside track in application to the automotive field. Some advantages of the gas turbine over present gasoline engines are: 1) more than 50% lighter with equal HP, 2) less maintenance, 3) cheaper fuel of lower octane without TEL, 4) less noise and vibration, 5) cleaner exhaust. Some disadvantages at present: 1) high cost to build, although mass production could help here, 2) slower throttling response, 3) sensitivity to temperature, 4) higher fuel use, and 5) exhaust too hot. When will we see gas turbine autos? Probably not before 1970 to 75.

Corrosion-Resistant Masonry

The unique subject of corrosion-resistant masonry construction, and pre-stressed brick linings in steel apparatus, both developments of the Germans during World War II, was presented by R. R. Pierce, Pennsalt, at the November meeting of the **Louisville Section** (*F. G. Smith, Jr.*). While brick offers good corrosion resistance, its use as a lining in steel process vessels has great difficulties caused by differing heat transmission and elongation between brick and steel, which will crack the lining. Solution of the Germans was to compress the brick during process of lining, imposing a tensile stress on the surrounding steel shell. The result is that the steel shell is always in tension, the brick-work under compression. Such a pre-stressed vessel can be lined with 1¼-inch brick and stand "cold shocking" without harmful effects.

INDEX OF ADVERTISERS

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Chicago 11—Richard R. Quinn, Dist. Mgr., 612 North Michigan Ave., Room 507, Superior 7-0385.

Cleveland 15—Eugene B. Pritchard, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

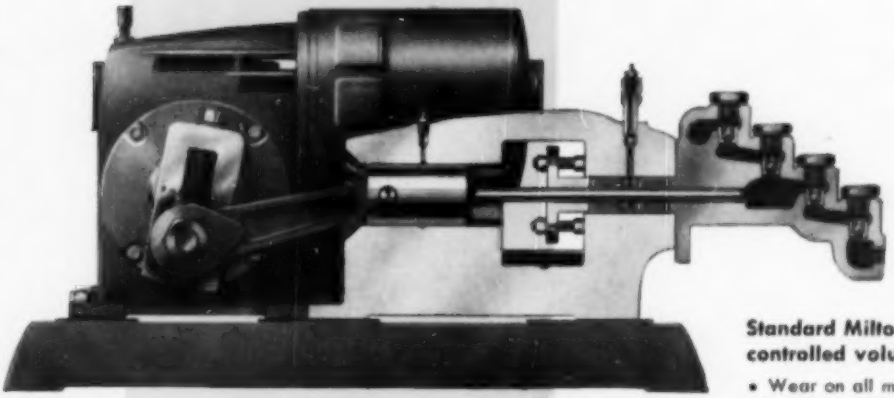
Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.

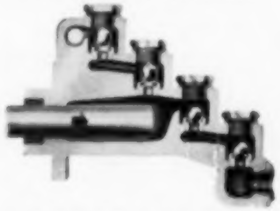
news and notes of A.I.Ch.E.

WHY News & Notes: Some history may not be amiss at this time concerning the purposes of this column . . . It is to give members quickly the important news of Council actions, A.I.Ch.E. policy, & current activities of members & local sections which may help to achieve the constitutional purposes of A.I.Ch.E.: "the advancement of Chemical Engineering in theory & practice" . . . This page is dedicated to communication, & in recent months its format & style have been altered . . . I hope that members will tell me how they like the change . . . Future columns will begin with a brief discussion of some phase of A.I.Ch.E. life (this month a few words about meetings) . . . The last part will be news: one- or two-sentence reports of events . . . Should anyone want to know more, I hope that he will send me a post card mentioning what he wants to know, & a complete explanation will be forthcoming . . . **About A.I.Ch.E. Meetings:** I assume that every member knows that we have four meetings a year & that the Program Committee tries to follow a specific pattern . . . The Annual meeting is by Constitutional decree held in either November or December . . . This is the big meeting—more members attend, & events include awards to outstanding chemical engineers, various lectures, a whole complement of committee meetings, plus a well-known speaker at the banquet . . . Added to this are three additional gatherings of the clan, our former Regional, now called National, meetings . . . These are deliberately planned geographically . . . The purpose is to enable all members, no matter where they are situated, to attend at least one meeting . . . to make it impossible for a chemical engineer not to have an opportunity to enjoy the fine programs put on by his fellow professionals . . . Of the three National meetings each year, one is a so-called "resort" type, held at some comfortable spa or club. . . . It has been found that all in all this kind of relaxed, informal gathering is as efficient as any other kind in imparting information, is as cheap as or cheaper than one in a metropolitan hotel, & achieves even better the happy objective of widening acquaintance. . . . **Nuclear Meeting:** Now one more meeting has been added—an annual nuclear meeting. The A.I.Ch.E. has, happily, been justified in the investment made in the Cleveland nuclear meeting held by all the engineering groups. . . . This was sponsored by Engineers Joint Council, and A.I.Ch.E. was able to recover the money it had put into programs & preprints. . . . There are more changes . . . Owing to a conflict in dates with a trade association show in the nuclear field &, more important, to an emerging pattern of cooperation in the nuclear field among the five basic engineering societies, the meeting of & exposition by the A.I.Ch.E. & its Nuclear Engineering Division will probably be held in Philadelphia the week of March 11 through 15, 1957, along with meetings of the four other engineering groups, instead of September 30-October 6, 1956, as originally announced. . . . A.I.Ch.E. invited other societies, & they have all accepted, in principle, the sharing of income from the exposition to be held at the Nuclear Congress . . . All this, it is planned, will be under the sponsorship of E.J.C., & the management & underwriting of the Congress will rotate among the engineering societies. . . . This marks an important step in intersociety cooperation, & the groups involved are able to explore the technology, the science, the management, & the economics of the whole nuclear field.

Registration fee increase was decided upon by Council . . . Under study for more than a year, registration fees at meetings were increased by $2 for Members, Affiliates, and nonmember chemical engineers and by $1 for Associate Members. . . . **Council appointed special committee,** chairmaned by a new Council member, D. F. Othmer of Brooklyn Polytechnic Institute, to study reasons why new graduates do or do not join the A.I.Ch.E. . . . Purpose is to determine what particularly influences the decision to join or what, in particular, prevents association with A.I.Ch.E. . . . Study will reveal valuable data for the future of A.I.Ch.E. and, more importantly, for the future of many young men yet to be graduated from engineering schools . . . **Numbers 54 and 55:** Welcome is extended to Memphis and to Idaho Falls as local sections of the A.I.Ch.E. . . . our fifty-fourth section had its petition approved by Council at the January meeting, and the fifty-fifth at the Los Angeles Meeting.

F.J.V.A.





FERMENTATION at Eli Lilly and Company, Indianapolis, produces erythromycin at high rates. Twelve 200-HP turbine-type LIGHTNIN Mixers achieve maximum gas-liquid contacting effectiveness in antibiotic broth. You can get LIGHTNINs like these, in hundreds of power-speed combinations, sizes 1 to 500 HP, for open or closed tanks.

How Eli Lilly minimizes risk *on large-scale mixing operation*

Mixing fluids in a big way? Then you know how vital it is to *be sure* about results, before you invest.

Eli Lilly's engineers *are* sure. After months of investigation, they selected these twelve 200-HP LIGHTNIN Mixers to speed up fermentation of erythromycin, a wide-range antibiotic, in tanks of 12,000-gallon to 15,000-gallon capacity.

The mixers have performed satisfactorily, as expected, since their installation in 1952.

No guesswork

You can be sure, too. Whatever the mixing operation, with LIGHTNINs you can count on getting the *one* just-right balance of fluid flow and fluid shear that gives you the results you want, with minimum cost.

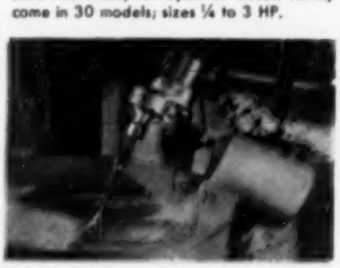
This is because MIXCO engineers are uniquely equipped to pilot-plant your operation, using standard calibrated mixing impellers with *fully-known power characteristics.*

There's no guesswork. Scale-up is accurate. Every LIGHTNIN Mixer is guaranteed, unconditionally, to do the job for which it is recommended.

That's just one reason—and a powerful one—why chemical and pharmaceutical leaders, such as Eli Lilly, more than ever, are standardizing on LIGHTNIN Mixers for *every* fluid mixing operation.

Want to know, specifically, how you can be sure of optimum fluid mixing? Your LIGHTNIN Mixer representative will be glad to show you. His name is in your copy of Chemical Engineering Catalog. Why not phone him today?

USING SPECIAL TANKS? You can get LIGHTNIN Mixers to fit them. Propeller-type units like these, for open or closed tanks, come in 30 models; sizes ¼ to 3 HP.



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Get these helpful facts on mixing: cost-cutting ideas on mixer selection; best type of vessel; installation and operating hints; full description of LIGHTNIN Mixers. Free—no obligation. Just check data you want, tear out and mail to us today with your name and company address.

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